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Municipal/Industrial Strategy for Abatement

A STUDY OF THE EFFECTS OF IN-PLACE POLLUTANTS ON THE BOTTOM WATER, SEDIMENTS AND SEDIMENT-DWELLING ORGANISMS OF THE GRAND RIVER AT KITCHENER-WATERLOO 1986 AND 1987

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A STUDY OF THE EFFECTS OF IN-PLACE POLLUTANTS ON THE BOTTOM WATER, SEDIMENTS AND SEDIMENT-DWELLING ORGANISMS OF THE GRAND RIVER AT KITCHENER-WATERLOO, 1986 AND 1987

Report prepared by:

R. Jaagumagi, T. Lomas and S. Petro
Watershed Management Section
Water Resources Branch
Ontario Ministry of the Environment

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SUMMARY

A survey of the sediment and bottom waters of the Grand River in the vicinity of Kitchener was carried out in 1986 and 1987 as part of the Municipal-Industrial Strategy for Abatement (MISA) Pilot Site investigations. The results showed that pollutant load from urban and rural non-point sources influenced the system to a greater degree than the Waterloo Water Pollution Control Plant (WPCP). The major findings are summarized below.

1. Discharge from the Waterloo WPCP resulted in elevated levels of sodium, chloride, sulphate, some of the metals and conductivity. The discharge however, does not appear to be having any effect on the sediment downstream of the WPCP.

2. There was no increase in sediment metal levels below the WPCP. Levels were actually higher upstream where organic matter had accumulated. Suggesting that the contributions from urban/rural non-point sources are more significant than the WPCP. Higher levels of lead and zinc were found in sediments below the drainage ditch discharges. Deposition of organic matter in the river is temporally and spatially variable. Where organic matter is low, accumulation of metals appears to be mainly into the clays and Fe/Mn oxides. Where significant accumulations of fine organic matter occur, such as at the confluence of Laurel Creek, metals appear to be accumulating with the organic matter.

3. Levels of most organic compounds were below detection limits. However, PAHs in sediments were elevated at upstream areas, specifically in depositional areas such as occurred where Laurel Creek joins the Grand River. Levels in sediments were considerably higher in 1987 than in 1986.

4. The biological results showed that invertebrate tissue levels of metals were generally higher at stations upstream of the WPCP. Invertebrates did not appear to accumulate detectable levels of any organic compounds. Little difference was noted in metal levels in fish tissue between upstream and downstream areas and tissue levels of organics were all very low.

5. Laboratory sediment bioassays indicated that none of the sediments were toxic to the species tested. Accumulation of metals paralleled field results.

6. A slight increase in benthic biomass below the WPCP may be in response to the discharge of the nutrients N and P from the plant. Aside from this, no other impact on the benthic fauna was discernible.

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1. INTRODUCTION

The Grand River in the area of Kitchener receives effluent from a variety of industrial and commercial sources. The Grand River receives inputs from the municipal sewage treatment plant in this area as well. The drainage area of the basin is under intensive agricultural use. Upstream areas can also contribute contaminants from industrial sources from any of the numerous sources along the Grand or any of its tributaries.

This study was part of the Municipal-Industrial Strategy for Abatement (MISA) Pilot Site investigation of the Grand River. The study also represents ongoing efforts by MOE to understand the movement of contaminants into and from sediments and to be able to predict their long-term fate and effects in the aquatic environment. Contaminants that enter the aquatic environment may exist in several forms: as distinct entities, dissolved in water, or attached to particulate matter, depending on the physical and chemical properties of the contaminant.

In an effort to understand the biological significance of contaminants in sediments the Ministry has developed an ecosystem approach for assessing sediments. This approach investigates the physical, chemical and biological aspects of sediment contamination. Physical studies provide information on the type of sediment, while chemical investigation provides information on contaminant levels in bottom water, sediments and the aquatic biota that inhabit sediments, including the bottom-feeding predators. The biological component can provide indications as to fate and movement of contaminants in biological compartments and their effects on the organisms. The latter are often determined on the community or population levels rather than effects on individuals.

2. METHODS

In June of 1986, 8 stations were sampled along the Grand River, from north of Bridgeport downstream, to Freeport (Figure 1). Sampling was repeated at 7 of these stations in November 1986 (Figure 2). Only sediments were sampled during the latter survey. Biota were not sampled in 1986. Of the eight stations sampled, six (A, B, C, E, F and H) were located on the Grand River itself while the remaining 2 stations (D and G) were located on inflow streams, mainly drainage ditches.

In May- June of 1987, three stations were surveyed along the Grand River in Kitchener. The stations were located upstream, at, and downstream of the Waterloo WPCP (Figure 2). The locations of the 1987 survey stations coincided only very roughly with the 1986 survey locations. Sediment and water samples were collected in a follow-up survey in October.

The study components in 1987 included: surficial sediment chemistry (top 5 cm), bottom water chemistry, and contaminant levels in benthic invertebrates (oligochaetes) and bottom-dwelling fish (longnose dace, emerald shiners, rainbow darters and white suckers). In addition, the fine-sediment fraction (<63 μ diameter) was analyzed using a sequential extraction scheme to determine the distribution of metals in the various geochemical phases (Persaud *et al.* 1987).

Bottom-water samples were collected by hand (no sites were deeper than 1m) on the last day of each field survey. Water temperature, pH and dissolved oxygen were measured and the sample was properly preserved according to the type of analysis required and submitted to the MOE laboratory. Samples were analyzed for nutrients, ions, metals, PCBs, organochlorine pesticides and chlorinated aromatics.

Sediment was collected by shovel. The top 5 cm from each of three samples was collected at each station and composited for sediment analysis. Most physical measurements were carried out in the field in accordance with the methods described in Persaud *et al.* (1987) and included sediment pH, redox potential, and sampling depth. Sediments were maintained at 4 C until analyzed.

Chemical analyses on sediment and bottom water were carried out in the MOE laboratory in accordance with procedures described in OMOE (1983). Sediments and bottom water were analyzed for nutrients, metals, PCBs and pesticides, PAHs, chlorinated aromatics, and sediment particle size.

Benthic organisms for contaminant analysis were also collected by shovel. A minimum of 2 gms of the most abundant organism was collected at each station for inorganic contaminant analysis, wrapped in plastic and immediately frozen. An additional 4-5 gms was collected for organic

contaminant analysis, wrapped in hexane rinsed foil and frozen. These were analyzed for PCBs and pesticides, PAHs and chlorinated aromatics as well as percent lipid content and ash. The percent ash was used to correct for gut content in determining tissue concentrations. Analyses were carried out by consultant laboratories according to the methodologies described in Persaud *et al.* (1987) and OceanChem (1988).

The most abundant bottom-dwelling fish were collected in an effort to gain an understanding of contaminant transfer between the various compartments (e.g., sediments, benthos, water, fish). Fish (approximately 6-10 cm total body length) were collected by seine nets and at each station a minimum of 15 fish were collected for tissue analysis. Fish from each station were grouped by species, age and length. The analyses were the same as those for benthic invertebrates.

A total of 5 replicate samples for benthic invertebrate community analysis were collected at each station using a stainless steel Ponar grab sampler (22.9 cm.x 22.9 cm (9" x 9")). Samples were field washed using a U.S. 30 mesh (595 um) sieve and the residue was preserved in 5-10% neutralized (with borax) formalin solution. Samples were sorted under a dissecting microscope. The densities of organisms were averaged over the total number of replicates and the replicate closest to the mean values was chosen for detailed identification of the organisms present. The remaining four samples were set aside for biomass determination.

Biomass estimates were calculated as preserved wet weight of organisms. Samples were blotted dry on filter paper to remove surface moisture and were immediately weighed to the nearest 0.1 mg on a Mettler H20T balance. The results were averaged over the number of replicate samples and the mean value has been presented in the tables. A correction factor of 10% has been added to the total preserved weight to attain the total live wet weight. Studies by Wiederholm and Eriksson (1977) and Landahl & Nagell (1978) have shown that on average a 10% weight loss occurs in preserved specimens due primarily to differences in densities between ethanol and water.

Laboratory sediment bioassay experiments were conducted on material collected from the Grand River in the area of the Waterloo WPCP on October 26, 1987. One sediment sample was collected per station from all 3 stations shown in Figure 1.

Sediments were transported to the MOE Rexdale laboratories, where they were stored at 4° C. Part of the sediments collected were used for analysis of the same chemical parameters measured in July. On January 11, 1988, the sediments were sieved through a 3 mm mesh sieve prior to use in the bioassay to remove large particles and debris as well as to homogenize the sediment. A total of 200 ml of sieved sediment was placed in a 1 l Mason jar to which 800 ml of dechlorinated tap water was added. Six jars were filled for each station and the sediments were allowed to settle for 24 hrs. before aeration was started. After 1 hr of aeration, test animals were added to the jars. The six test jars for each station were divided into two groups of three jars each. Five fathead minnows (*Pimephales promelas*) were added to each of the three jars in the first group and five nymphs of the burrowing mayfly *Hexagenia limbata* were added to each of the three jars in the second group. The minnows used were cultured in the MOE Rexdale laboratory and were all 3 months of age. The mayflies were second year nymphs collected at Honey Harbour (an uncontaminated site) on Georgian Bay. Honey Harbour sediments were used for the experimental control.

The bioassay was run for a total of ten days in a controlled water bath at 20° C and was monitored daily during this time for any mortality at which time any dead animals were removed. At the end of the ten day period the surviving animals were removed, frozen, and subsequently submitted for analysis of tissue contaminant levels. In order to obtain sufficient biomass for tissue analysis, the surviving mayflies from all three replicates were pooled. One replicate for fathead minnows (greatest number surviving) was selected for analysis.

3 RESULTS

3.1 Bottom Water

Water samples were not obtained during the 1986 study. Data from the more limited 1987 study are presented in Tables 1 to 5.

A number of parameters increased downstream of station 0002. Conductivity, sodium, chloride and sulphate levels were all significantly higher in bottom water at station 0001, downstream of the Waterloo Water Pollution Control Plant (WPCP) discharge, and continued high through station 0003 (Table 1). Suspended sediment and

phosphorus levels also increased at station 0003 as did nitrite levels.

Metal levels were generally below detection limits (Table 2). However, detectable levels of copper, chromium, iron, zinc, manganese and aluminum were noted at some stations. For example, water concentrations of iron and aluminum were higher at station 0001, downstream of the WPCP discharge, while levels of all others were higher at stations 0002 and 0003. The WPCP may be contributing higher levels of these two metals to the river, though data from station 0003 suggest this effect may be limited. Levels of most organic compounds were below detection limits (Table 3 to 5).

The STP discharge appears to affect water quality mainly in terms of increased levels of salts, nutrients, suspended solids and some of the heavy metals.

3.2 Sediment

3.2.1 Physical Characteristics

Sediment data for both the 1986 and 1987 surveys are presented in Tables 6 to 13. Sediments in the study area in 1986 were highly variable in organic content and ranged from a high of 24 mg/g TOC to less than 5 mg/g. These most likely reflected the flow regime of the river. Sediments in the inflow streams were generally very low in organic matter and suggest higher current velocities.

Station A was located at the mouth of a small bay and reduction in current velocity associated with this embayment likely contributed to the higher organic content of the sediments (Tables 6 and 7). Data from the November 1986 survey show that substrate at station A was mainly a silt-sand mixture. There is no corresponding station from the 1987 study.

Station B was located in a mainly sandy area downstream of the mouth of Laurel Creek, though still upstream of the WPCP. Particle size data from the November survey shows that sand formed 95% of the substrate with only a minor silt fraction. Given the higher organic carbon content in June, silt likely formed a slightly higher percentage of the substrate in the spring. Station 0002, the upstream control in the 1987 survey, corresponds to station A in substrate type, which was comprised of a roughly even mixture of sand and silt as well. However, station 0002 actually corresponded to station B in terms of location, since it was situated at the mouth of Laurel Creek. Biota collected during the benthic enumeration study of May-June 1987 included large numbers of the isopod *Asellus*, which are usually found in association with coarse organic matter. The suggestion is therefore, that this was a depositional area of the river where not only fine organic, but also coarse organic matter has accumulated.

Station C was located approximately 100 m downstream of the Waterloo WPCP discharge. Sediments were a relatively even mix of sand and silt, low in organic content. Station 0001 (1987) corresponds roughly with station C, though station 0001 was located about 1000 m downstream of the WPCP discharge. Substrate type in this section of the river was similar in both years and consisted mainly of sand and silt, though the concentrations of each were variable and ranged from a high of 52% silt in June 1987 to a low of 32% silt in November 1986.

Station 0003, sampled in 1987, was situated ca. 2 km. downstream of station 0001, also in a sand-silt mix. There was no corresponding station sampled in the 1986 study. The remaining river stations (stations E, F and H (1986)) were primarily sand substrates, low in organic matter. No stations were sampled in 1987 that correspond to these stations. Temporal changes in discharge would likely prevent the accumulation of significant amounts of organic matter except in protected areas such as station A.

Sediment organic content was highly variable, though levels were generally substantially higher in 1987 (Table 7b) than in 1986. The pattern of sediment distribution suggests that bottom sediments are relatively mobile and that significant accumulation of surface sediments depends to a large extent on temporal and spatial variations in discharge and flow dynamics.

Levels of solvent extractables (oil and grease) were also highly variable (Table 7) with the highest levels in 1986 recorded at the upstream control and the furthest downstream station (station H). Since both of these stations also had the highest sediment organic carbon levels, the oils and grease appear to be accumulating in the softer, fine-grained sediments that have settled in these depositional zones and may be contributing to the organic carbon content. Levels were considerably lower in

areas of primarily sand substrates, most likely due to current factors. Levels in the storm sewer discharge ditch were significantly lower than in the river or the Breslube Ditch. Discharge in some, such as the storm weir, was highly intermittent, with flow occurring in these channels only during spates (R. Jarvis, Pers. comm.). This would provide little opportunity for material to settle into the sediments and most would therefore be washed into the Grand River.

Sediment concentrations of solvent extractables in 1987 were considerably higher (by nearly 2 times) at the upstream control (station 0002) than in 1986 and are likely due to the higher organic content of the sediments. Downstream areas were comparable with similarly silty sediments in 1986.

3.2.2 Metals

Sediment metal levels appeared to vary in relation to levels of organic matter in 1987 but not in 1986. Sediment metal levels in 1986 increased at downstream stations despite low organic content (Table 7a). Geochemical fractionation data from 1987 suggests that most metals downstream of the WPCP are bound to the more resistant (F4 and Residual) fractions of the sediments and thus may be associated more with Fe/Mn oxides and clays than organic matter (Table 8). The current may remove much of the organic matter and the metals in sediments therefore appear to be those bound firmly to the less erodible bottom materials.

Poor correlations were obtained between metal levels and sediment organic matter in 1986, but significant levels were obtained between some metals (Cd, Fe, Cu, As and Ni) and sediment TOC in 1987 (Table 27). Since both sediment TOC and metal concentrations were higher in 1987, this suggests that metals are accumulating with particulate matter. Most likely these originate in the water column, where they bind to suspended particles and subsequently settle out (Sigg *et al.* 1988).

Levels of metals in sediments were generally low in 1986 (Table 7a) and no exceedances of the Severe Effect Level of the draft Sediment Quality Guidelines (Persaud *et al.* 1990) was noted for any metal at any station. Levels of some metals did exceed the Lowest Effect Levels at the stations downstream of the WPCP. Levels of most metals were lowest at station A despite the higher sediment organic content, and likely represent background levels in the upstream sediments. Levels increased at station B, despite the much lower sediment organic content, though levels were still lower than stations further downstream. By comparison, levels at the 1987 control station (0002), which corresponded to station B in terms of location, were considerably higher (Table 7b) and in the case of copper, chromium, lead and zinc, exceeded the Lowest Effect Level of the Sediment Quality Guidelines (the Lowest Effect Level is the sediment concentration at which some sensitive benthic organisms may be affected). Levels of Cu and Cr were approximately 2 times higher in June 1987, though these levels decreased to near 1986 levels by the October sampling period. This would seem to be primarily due to the decreased TOC levels. Mercury levels in spring 1987 were ca. 10 times higher while lead, zinc and arsenic were 12, 6 and 4 times higher respectively. Concentrations of all of these metals decreased in the fall to 1986 levels as TOC levels fell. The Grand River evidently receives significant inputs of metal contaminated sediments within its watershed and deposits this material during periods of low flow. These accumulations appear to be washed out by the river during periods of high discharge.

In the June 1986 study, sediment metal concentrations at stations downstream of the WPCP increased slightly with increasing distance downstream (Figure 3). Levels were generally higher at station C and reached the highest levels at station E. Settling of contaminated suspended matter at station E from upstream sources, such as the storm sewer discharge ditch and the WPCP could account for this increase. Increased sediment concentrations below the WPCP were noted, despite the low sediment organic matter and the primarily sand substrates. Sediment metal levels actually decreased downstream of the WPCP in November, such that the highest metal levels in many cases occurred at station A, the control (Table 7a). Flushing of sediments in the downstream sections appears to occur during periods of high discharge, while sediments at station A, located in a relatively protected area, do not appear to be eroded to the same degree. A similar pattern was observed in 1987, where sediment metal levels were, in most cases, lower in October. As in the 1986 study, the highest levels of many metals (all except lead) were recorded at station 0002, the control for the 1987 study. The elevated lead levels at station 0003 are probably due to the storm sewer weir, which discharges to the river between station 0001 and 0003. The weir drains, among other sources, an auto wreckers and an ash disposal site. Both could be a

source of elevated levels of lead to the sediments. It is apparent that sediment metal levels appear to be controlled by deposition and resuspension of suspended matter and, at least in 1987, were highest in areas where organic sediments had accumulated. There appears to be an increase in the levels of some metals (e.g., cadmium, iron and strontium) in sediments below the WPCP discharge.

Sediment metal levels were variable in the two drainage ditches sampled (station D and station G). Flow in the storm sewer discharge (station D) is highly intermittent and the ditch can be dry for extended periods. Substrates in both the Breslube Drainage Ditch (station G) and the storm sewer discharge stream (station d) were low in organic matter and data from the November study indicates that sandy sediments predominated in both channels (Table 6). The similarities in sediment organic matter suggest that there is little change seasonally. Metal levels were higher in the storm sewer discharge during both sampling seasons for copper, chromium, lead, zinc, iron and arsenic than in the Breslube ditch and levels were similar to nearby Grand River sediments (station E). Given the low organic content of these sediments, these levels can be considered as relatively high. Under the highly irregular nature of discharge in these drainage ditches, most of the sediments appear to be washed out into the Grand River, with very little accumulation in the ditches themselves.

3.2.3 Geochemical Fractionation

Metals will often bind preferentially to different components of the sediment. The sequential extraction scheme is an operationally defined process that separates the various components in the fine-particle (<63 u) fraction. The concentration of metals can be measured in each of the following geochemical phases:

IW - Interstitial Water
F1 - Cation Exchangeable Fraction
F2 - Easily Reducible or Carbonate Bound
F3 - Organic Complex
F4 - Fe/Mn Oxide Fraction
Res- Residual Fraction

The significance of each fraction is discussed in Persaud *et al.* (1987) and Tessier (1979). The results of the geochemical extraction procedure for the 1987 spring (May-June) data are presented in Table 8 and Figures 5a through 5j. No comparable data are available from the 1986 surveys.

Levels of Al in the various sediment fractions remained unchanged below the WPCP discharge (Figure 5a). Levels were highest in the Residual fraction and suggests that the Al present is naturally deposited through weathering of local rock. Levels were low in the other fractions. Only iron was similarly distributed in the sediments and suggests a similar mechanism of deposition. However, sediment concentrations, particularly in 1986, increased below the WPCP at station C. In November, levels were lower at station C while the highest levels occurred at station A. Levels in 1987 were similar at stations 0002 and 0001 but were higher at station 0003. The highly variable pattern of sediment distribution, therefore, suggests that accumulation is from general sources in the watershed and that this metal is being deposited and eroded along with sediment fine particles. However, there are indications that the WPCP is also contributing to these higher levels below the outfall.

Arsenic was present mainly in the Residual fraction at downstream stations, though levels did increase significantly in the F2 and F4 fractions at the control (Figure 5b). Bulk sediment levels in 1986 were relatively consistent among stations and showed a minor increase at station B in June. Levels in 1987 were generally highest at the upstream control. No specific source can be identified and the distribution pattern is highly suggestive of the co-accumulation of As with sediment fines particles and/or organic matter.

Chromium, lead and zinc showed similar increases in the more easily exchangeable fractions at station 0002, with larger amounts in the residual fraction at downstream locations (Figures 5d, 5g, and 5j). This station therefore seems to be receiving relatively recent material, likely in conjunction with deposition of organic matter. Bulk sediment levels of chromium and zinc were both highest at station 0002 in 1987, while levels of lead were highest at station 0003 (Figure 4). The latter may be due to discharge of lead or lead contaminated sediment from the storm sewer. Levels of all three were higher at downstream stations in 1986, with the highest levels at station E. Settling of contaminated material appeared to occur in this section of the river.

Andrews (1988) observed the movement of zinc in sediment fractions over time and noted that increased residence time leads to an increase in the residual fraction as the metal moves through the less tightly bound fractions. Evans *et al.* (1988) suggested a similar movement of cobalt in

sediments. The presence of higher metal levels in the IW to F3 fractions relative to levels in the F4 and Residual fractions suggests that the origin of the metal concentrations in the sediment is comparatively recent. Higher concentrations in the IW to F3 fractions also has implications for bioaccumulation of metals and this is discussed in the next section.

Levels of cadmium in the various sediment fractions were relatively evenly distributed among all of the fractions except the IW (Figure 5c). Levels were consistently high in the F3 fraction and suggest that much of the Cd has accumulated in conjunction with organic matter. Cadmium levels in bulk sediment were higher at station C in June 1986, but decreased again in November. Like most of the metals, sediment levels seem to depend on depositional characteristics of the river.

Copper showed a similar trend to cadmium, with lesser amounts present in the Residual fraction, while the largest percentage was in the F3 and F4 fractions (Figure 5e). As with the previously mentioned metals, levels were highest in the more readily exchangeable fractions at station 0002, and decreased relative to the Residual fraction at downstream stations. The implications are that these metals are also accumulating in the sediments where flow characteristics favour the deposition of suspended material.

Manganese was present mainly in the F1 and F2 fractions and this relationship remained relatively constant, though the actual levels did vary (Figure 5h). Nickel was present in nearly all sediment fractions, except IW, in relatively equal amounts (Figure 5i).

The distribution of metals suggests that some of the metals present in the sediments are due mainly to natural sources within the watershed. Only Al and Fe were present mainly in the F4 and residual fractions and likely have originated from natural sources (weathering of rock). The presence of most of the other metals in the more available fractions suggests that deposition in conjunction with various sediment organics and other fractions has occurred, likely through deposition of suspended particulates. This seems to be especially prevalent at station 0002 where high levels of both metals and fine organic matter have accumulated.

Distribution of metals in sediments appears to be controlled by the depositional regime and hence the flow characteristics of the river. Metal levels at various locations along the river appear to increase and decrease as sediment material is eroded and deposited. As a result, no clear indication of sources seems to exist. Spatial and temporal variation in accumulation of sediment fines and organic material are major confounding factors.

3.2.4 Organic Compounds

Levels of PCBs and organochlorine insecticides were generally below detection limits in the Grand River in both 1986 and 1987 (Tables 9a and 9b), though high levels of PCBs were detected in sediments at station 0002 in May-June of 1987 (concentrations exceeded the Lowest Effect Levels of the Sediment Quality Guidelines). However, levels were again below detection limits in October, which suggests that sediment accumulation of PCBs was extremely local, or that the contaminated sediment was transient and was resuspended and deposited further downstream. The latter may be the more likely, given the relatively high discharge. Levels in the drainage ditches sampled in 1986 (stations D and G) were also generally below detection limits (Table 9a).

Levels of PAHs were generally rather high in both 1986 and 1987 (Table 12) . The most prevalent compounds were, phenanthrene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[k,b]fluoranthene and benzo[a]pyrene, nearly all of which are anthropogenic in origin. Highest sediment levels in 1986 of all of these were recorded at station B, upstream of the WPCP discharge. High levels were also recorded at station E, though levels were generally lower than at station B (Figure 6). Wakeham *et al.* (1980) suggest that urban runoff is usually the largest single source of PAHs in areas where specific sources such as smelters are absent. Automobile exhaust can contribute significant quantities of PAH.

Sediment concentrations of PAHs were as high, or higher, at stations 0002 and 0003 in 1987, and suggest that these compounds sorb rapidly to suspended matter and are subsequently deposited in sediments in this form. Total PAH at station 0002 was 33.86 μg/g, which is well above the Lowest Effect Level of the draft Sediment Quality Guidelines. Levels at station 0002 for a number of PAHs were significantly higher in 1987, as shown in Figure 6, than at the comparable stations sampled in 1986. Levels at station 0002 were also considerably higher than levels downstream, which were more comparable to 1986 levels. The relatively

higher accumulation of organic matter as denoted by LOI at station 0002, may account for this since the affinity of most high molecular weight PAHs for suspended organic particulates has been well demonstrated. Like the metals, the PAHs appear to be originating from sources in the watershed and accumulating in areas of lower current.

Levels of most PAHs were considerably lower at stations D and G in 1986, with levels in the storm sewer discharge ditch (station D) (Figure 6f) less than one half the levels in sediments in the Grand River. Since these are designed to carry off storm water, and are as a result highly intermittent in flow, accumulation of sediments would be relatively minor in these channels. Sediment grain size data shows that substrates were mainly sand and gravel, with very little accumulation of fine material. However, given the low organic content at most of the stations in 1986 and the predominantly sand substrates, concentrations in the river sediments can be considered relatively high. Umlauf and Bierl (1987) estimated that the fine silt and clay fractions carry 60-70% of the total PAH load, which suggests that levels in suspended sediments in the Grand could be considerably higher than the levels recorded here. This is in part demonstrated by the considerably higher levels in sediments at station 0002 (1987), where silt and clay were much more prevalent.

Levels of other organic compounds in sediments were below detection limits in 1986 and 1987 (Tables 10 and 13). These compounds, if in fact they are present in discharges to the river, do not appear to be accumulating in the sediments.

3.3 Aquatic Biota Contaminant Analysis

3.3.1 Benthic Invertebrates

The geochemical distribution of metals in the sediment can directly influence the availability of the metals to aquatic organisms. Studies (Luoma 1983; Smock 1983) have suggested that 80 to 85% of an organisms body burden may be acquired by adsorption of metals through the integument or cuticle (Knowlton *et al.* 1983) and that the free ion concentration in the interstitial water is usually the most available phase. However, sediment-bound metals may contribute significantly to an organisms body burden, depending on the metal as well as on the availability from the sediments. The efficiency of uptake has been shown to be much greater from the water phase as compared to efficiency of uptake from ingested matter (Luoma 1989). However, the much larger sediment concentrations often means that ingestion may contribute significantly to organism tissue concentrations of certain metals under certain conditions.

Sorption of contaminants by sediments and desorption to the water phase are believed to be continuous exchange processes (Stumm & Morgan 1981). Levels of metals and organic compounds available to biota from the water phase would therefore depend on levels available in the solid phases of the sediments. As such, in areas of contaminated sediment, even minute concentrations in the interstitial water or bottom water could contribute significantly to an organisms body burden through a more or less continuous availability of the contaminant. This depends mainly on ease of release from the solid fractions to the interstitial water, which appears to be the main medium of uptake by aquatic organisms (Luoma 1983; McElroy *et al.* 1989).

Metal accumulation by benthic biota appears to be a complex process that cannot be described by any simple relationship between sediment or water levels, and tissue levels. Accumulation is affected by a large number of factors, and tissue levels are the sum of adsorption from the water, desorption from the sediment and absorption from ingested matter. Depending on sediment characteristics, the amount contributed from each of these processes can vary. It is generally recognized however, that the most efficient means of uptake is through adsorption of free ions from the water column or those desorbed from the sediments. Desorption of metals is itself a complex relationship affected by a number of physical and chemical factors such as pH, redox potential (Eh), organic matter, Fe/Mn oxides, clay minerals, and particle size.

Correlation analysis (Spearman Rank Correlation) between tissue metal levels and the amounts held in the various geochemical fractions yielded poor correlations between body burdens and all sediment fractions (Table 27). Metals held in the solid fractions (F1 to F4) are generally considered to be potentially available to aquatic organisms (Persaud *et al.* 1987). Availability decreases somewhat from the F1 to the F4 fraction as binding strength to the sediments increases and potential for release to the water (mainly the interstitial water) decreases. Metals bound to the F4 fraction (Fe/Mn oxides/hydroxides) are usually unavailable except under reducing conditions (Stumm & Morgan 1981).

Metals held in the organic fraction, though potentially available, can also be tightly bound and may not be easily removed under the gut conditions of most benthic organisms (Luoma 1983). Nevertheless, metals held in the F1 to F3 fractions are potentially the most available to benthic organisms, since these are the most readily extractable.

Metals held in the residual fraction are usually not available to benthic organisms nor do they readily release to the water. These are the most tightly held metals since they are bound within the crystal lattices of minerals (clays etc) and are not available under natural conditions.

Since, in the case of metals, 15-20% of an organism's body burden can be acquired through ingestion of contaminated sediments, the presence of contaminants in the more readily available fractions could serve to facilitate uptake and tissue concentration by means of digestive processes. The presence of metals in these fractions could also serve to increase the availability of these metals in the interstitial water.

Biota-sediment concentration ratios are presented in Table 12. Since the biota levels are a factor of uptake from both sediment and the water column (though the contribution from the latter is likely to be minor in the case of sediment in-fauna), the term bioconcentration has been avoided. For sediment in-fauna, this ratio can be used as an expression of the availability of contaminants from the sediments. A high ratio denotes that levels in organism tissue were higher than levels in the sediments which, in turn, suggests that availability from these sediments is high. It must be borne in mind, however, that a high concentration ratio does not necessarily imply high tissue levels but merely measures tissue levels relative to sediment levels.

Benthic organism tissue concentrations could not be related to levels of contaminants in the water column, in part because levels in the latter were generally very low. Other studies have indicated that metals tend to bind to organic matter and iron/manganese oxides in the water column and that most of the contaminant load is rapidly transported to the sediments (Sigg *et al.* 1988).

As it has yet to be proven that no differences exist in contaminant uptake among different species, the non-lumbricid oligochaetes are considered separately from the lumbricid oligochaetes.

Benthic invertebrates for tissue contaminant analysis were collected only in May-June of 1987. Sufficient specimens for analysis were obtained only at stations 0002 and 0001 and this small sample size precluded any statistical analysis. The lack of comparability therefore severely limits the usefulness of this data.

Only tissue lead levels and arsenic levels (Figure 7a) showed major differences between station 0002 and 0001. Tissue levels of lead were 3 times higher at station 0002 in both lumbricid and non-lumbricid oligochaetes while tissue arsenic levels were ca. 4 times higher at station 0002 (Table 11). Sediment concentrations of both of these metals were higher at station 0002 and since larger concentrations were available in the more easily reducible fractions (F3 for Pb; F1 and F2 for As) at station 0002, these may account for the higher tissue levels.

Tissue levels of the other metals varied only slightly among the two stations (Table 14). Tissue accumulation of metals to levels higher than in sediment occurred only for mercury (Figure 7c), zinc (Figure 7d) and arsenic at both stations 0002 and 0001, while significant accumulation of Cu (Figure 7b) and Cd, to above sediment levels, was found only at station 0002.

Tissue accumulation of PCBs and pesticides was generally below detection limits at both stations for both groups of organisms (Table 15). Similarly low levels of other organic compounds were detected in tissues with most levels below detection limits.

Levels of some of the more highly chlorinated phenols were above detection limits in tissues (Table 17). Levels of 345 Trichlorophenol were higher in oligochaetes at station 0002 as were levels of pentachlorophenol (PCP). Levels in oligochaetes at station 0001 were only slightly above detection limits.

3.3.2 Fish

Comparison of body burdens in fish was considerably more difficult due to the variety of species tested in the river. Only rainbow darters were caught at all three stations. Longnose dace and white suckers were caught only at stations 0001 and 0003 and no upstream control exists for these species. As a result, only similar species are

compared, though a general overview is also attempted. However, this analysis has been further complicated by the presence of different age classes at different stations. The darter caught at station 0002 was a two year old fish while those at station 0003 were determined to be one year old specimens. With the exception of station 0003, only one specimen of each species was analyzed at each station. Fish, as water column organisms, are generally exposed to contaminants primarily in this medium and only in the case of some of the persistent organic compounds, mainly those with very low water solubility, do food sources appear to be important (Chapman 1987). Therefore, it is difficult to ascribe tissue residues, with even a reasonable degree of confidence, to sediment sources. Fish tissue residues must therefore be interpreted with extreme caution.

Tissue metal levels in rainbow darters were similar in fish caught at all three stations (Table 18). Variability among the two specimens caught at station 0003 was in some cases greater than variability among the different stations. Arsenic and lead, both of which were accumulated to higher levels in benthos at station 0002, were only slightly higher in fish tissues at this station.

Levels of PCBs and most of the organochlorine pesticides were below detection limits in all fish at all stations (Table 19). The most notable exception was pp-DDE. Levels of this DDT metabolite, though elevated, generally varied little among stations, and levels upstream were similar to tissue levels downstream.

Tissue levels of a-BHC and endosulfan sulphate were also above detection limits, but tissue levels were low (Table 19). The distribution of all of these persistent organic compounds indicated that body burdens are due to generalized contamination within the watershed, most likely due to previous widespread use of agricultural pesticides in this area, and not to a specific source. The generally insoluble nature of these compounds suggests that sediment sources, most likely contaminated food, rather than water would be the major route of uptake.

Tissue levels of some of the other chlorinated organics were also above detection limits. Most notable, were hexachloroethane, 123 trichlorobenzene, and hexachlorobutadiene (Table 20). Tissue levels showed little difference in fish caught upstream as opposed to those caught downstream, and a general source in the water shed seems most likely. Since these compounds are relatively more soluble than those noted above, water and not sediment would seem to be the mot likely source of uptake by the fish.

Pentachlorophenol was the only chlorophenol that was detected in fish tissues (Table 21). Tissue levels in darters did show a slight upward trend with distance downstream, though whether this is due to local sources cannot be determined on the basis of the limited data.

Tissue levels of PAH compounds were generally below detection limits (Table 22). Only pyrene was detected in tissues of more than one specimen and the data shows a trend towards higher tissue levels in darters from station 0002 to station 0003.

In general fish tissue levels of all contaminants were similar at upstream and downstream stations.

3.4 Sediment Bioassay

The results of the acute toxicity bioassay are presented below. The percent mortality over the ten day period is shown for both mayflies and fathead minnows.

Station	Fathead Minnows	Mayflies
0002	0	5.0
0001	0	13.3
0003	0	6.7

The results show that the sediments were not acutely toxic to mayflies at any of the stations over the ten day test period. The highest mortality among the mayflies was observed at station 0001 but was low and reached only 13.3%. Mortality at all stations was low and could be attributable to other causes such as sediment type (sediment was coarse and not suitable for burrowing).

No mortality was detected among the fathead minnows in any of the test sediments.

Accumulation of contaminants to levels above those in control sediments was observed only for some of the metals (Table 23). Arsenic was accumulated in mayfly tissues to highest levels at station 0001 and would suggest that As was more

available from the sediments at this station (Figure 8a). Since field data showed lower levels of As in oligochaete tissue at station 0001 than at station 0002, mixing of the sediments may have enhanced the availability of As at station 0001. However, it is possible that a steady state condition had not been reached during the ten day test period.

Of the remaining metals, cadmium, chromium, copper, iron and lead, were all accumulated by mayflies in station 0002 sediments to higher levels than at either of the other experimentals or the controls (mean concentration)(zinc levels in tissue, though also slightly higher in those kept in the experimental sediments, were highest at station 0003) (Figure 8). This is consistent with the observed pattern of accumulation of metals by oligochaetes, which accumulated the highest body burdens at station 0002. The generally larger amount of metal available in the F1 to F4 fractions at this station may have been a factor in the greater rate of uptake of these metals both in the natural population of oligochaetes and in the test population of mayflies.

Levels of other metals in mayfly tissues in those animals kept in the experimental sediments did not differ from the controls.

Fathead minnows generally accumulated lower tissue levels of metals than did the mayflies. The exceptions were copper (Figure 8b), mercury and zinc, all of which were higher than levels in mayfly tissues in the control organisms. Levels in the experimentals for copper and zinc were slightly higher than in the control fish, suggesting that some additional metal had been accumulated during the course of the experiment.

Two of the organic compounds were also found in the test organisms at higher levels than in the controls. Levels of 1234-tetrachlorobenzene were found at significantly higher levels both mayflies and fathead minnows maintained in station 0001 sediments (Table 25). Tissue levels in both were approximately 2 times higher than at the controls or the other experimentals. Sediment levels at station 0001 were below detection limits. Mayflies kept in station 0002 sediments also accumulated slightly higher tissue levels of HCB than in the control mayflies. However, tissue levels in the controls were highly variable and this higher level may not be due to sediment effects but may merely represent the background levels of the test population.

Accumulation of other organic compounds was not apparent from any of the test sediments.

3.5 Benthic Enumeration

The three stations sampled in the Grand River for benthic community analysis in May-June 1987 were all similar in substrate type, which consisted mainly of a sand-silt mix. At all three stations the oligochaetes, of which the most common was *Limnodrilus hoffmeisteri*, were the dominant organisms.

At station 0002, while oligochaetes comprised 83% of the fauna a large population of the isopod *Asellus* was also present (Table 28). Fine sediment feeders though comprised 98% of the fauna with the ceratopogonids as the only predators (Table 29).

A similar distribution of organisms was present at station 0001 though the density of the worms was much higher at this station (Tables 28 and 29). The average weight per worm was also higher (28 ug) than for either of the other two stations (ave. 14 ug) indicating more favourable conditions. While levels of organic material were slightly lower at this station in comparison to the other two stations, levels of contaminants were similarly reduced and therefore no clear-cut reason for this difference is apparent.

Located furthest from the STP outfall station 0003 showed little difference from station 0001. Densities and biomass values were very similar as were the levels of contaminants.

The Grand River, at least in the area surveyed can be characterized as organically enriched. The domination of the benthic fauna by the oligochaetes, which were represented almost exclusively by *Limnodrilus hoffmeisteri* and the high density of sediment fine particle feeders in general attest to this. The locally high levels of PCB's at station 0002 seem to have had little effect on the fauna. Presumably these were present in a form unavailable to the organisms, or possibly were bound to various oils which could, and likely would, be avoided by the benthic fauna (McMurty, 1984). The sewage treatment plant appears to have little impact on the benthic community. The Grand River runs for much of its length through agricultural areas, and the origin of most of the organic material, for which station 0002 can be regarded as

typical, is most likely as agricultural runoff (both soils and fertilizers).

Biomass

Biomass changes in the Grand River show a somewhat different pattern. Both station 0002 and 0003 had lower densities and lower biomass of benthic organisms (Table 28). Organic content was also higher at these two stations mainly as a result of the higher silt content. This alone however does not seem to explain the differences in the populations among these two stations and station 0001, which had both a higher density and individual size of worms. Increased competition from other organisms (oligochaetes formed a greater percentage of the population at station 0002) may have been a contributing factor.

The high oligochaete biomass at all stations, and the increase at station 0001 suggests that the WPCP may be contributing to an area that is already defined as organically enriched.

4 DISCUSSION

The results of the bottom water analysis of 1987 indicate that the Waterloo WPCP is contributing to elevated levels of some parameters, specifically higher levels of some of the metals (Fe and Al), chloride, sodium, sulphate and higher conductivity levels. Upstream concentrations of these parameters were significantly lower than immediately downstream. Levels furthest downstream, at station 0003, were higher than at station 0001 and probably reflect greater mixing of the effluent plume, resulting in higher concentrations in the bottom water.

The results from both the 1986 and 1987 surveys indicate that sediment contaminant conditions in the Grand River are highly variable. Levels in the sediments appear to be influenced primarily by the amount of organic matter. The distribution and accumulation of organic matter is in turn determined by the discharge of the river which changes over time and varies along the course of the river.

Sediment metal concentrations were generally relatively low and concentrations seemed to be related mainly to particle size and organic content. In 1986, levels were lowest at the control station A, located furthest upstream. Levels increased at station B, below the confluence of Laurel Creek. An further increase in sediment concentrations of some metals (lead and zinc) was noted in downstream areas. Since levels of neither had risen at those stations directly below the WPCP it would appear that the WPCP discharge is not a source of these contaminants. Levels in the storm sewer ditch (station D) were actually higher and would appear to be a more significant source. The storm sewer discharge ditch drains an auto wreckers and an ash disposal site and both of these could be a source of lead or zinc to runoff water. Levels of solvent extractables were relatively high, though these were also highly variable. Again levels below the STP discharge were lower than upstream and downstream stations.

The 1987 survey produced similar results and showed that upstream areas of higher organic matter accumulation had higher sediment levels of most metals. The control in 1987 was located downstream of the confluence of Laurel Creek. Sediments from this area in both 1986 and 1987 suggest that contaminated sediments from upstream areas of the watershed are carried downstream to depositional areas such as near the mouth of Laurel Creek. These upstream sources could be any or all of a number of sources such as tributary streams, small industries, agricultural practices, and urban drainage. Levels downstream of the Waterloo WPCP were actually lower and reflect the lower organic matter content of the sediments. Therefore, there was no true control in the 1987 survey, since the control station, 0002, apparently is more heavily impacted in terms of sediment contamination than the stations downstream of the WPCP. Levels of most metals were actually lowest at station 0001, which was immediately below the WPCP discharge. Levels of lead, nickel and aluminum were higher than upstream at station 0003, and are likely the result of the storm sewer discharge.

In general the distribution of metals in sediments downstream of the Waterloo WPCP could not be related to any specific source, with perhaps the exception of lead and zinc. The downstream sediment concentrations of these two metals appears to be related discharge from the storm sewer drainage ditch. Levels of the other metals appeared to vary only in relation to deposition of particulate matter, and levels were highly variable seasonally and spatially.

Geochemical fractionation of the fine-sediment fraction in 1987 indicates that most of the metals were present in the less biologically available

sediment fractions (F4 and Residual). However, lead, nickel, cadmium and zinc were present at the upstream control in the more easily exchangeable fractions (IW to F3) and were potentially more available to aquatic organisms. This may have accounted for the slight increases in body burdens of these metals in the benthic organisms at station 0002. However, it must be borne in mind that the geochemical fractionation of the sediments by the sequential extraction procedure merely measures the sediment bound metals in operationally defined extractable phases and these may not necessarily reflect the natural distribution of metals in sediments. Therefore, while the extraction procedure can be useful in providing an indication of the distribution of metals in various sediment phases, these are not necessarily indicative of the available concentrations of these metals to either the interstitial water of biota.

Sediment levels of organic contaminants such as PCBs and the organochlorine pesticides and the chlorinated organics were generally below detection limits and no significant accumulation was noted. The source of the single high sediment concentration of PCBs in 1987 could not be determined. While sediment appears to collect near the mouth of Laurel Creek, it is most likely that this material originates upstream within the Grand River or its watershed, and not specifically within Laurel Creek itself.

A number of the PAH compounds appear to have accumulated in sediments. The distribution of these does not appear to be related to sediment organic content, but appears instead to be related to sources of input. The highest accumulation in both 1986 and 1987 was downstream of the mouth of Laurel Creek. However, the origin of this material is uncertain, as noted above. Urban drainage and perhaps other sources appear to be contributing PAHs to the Grand River watershed, with contaminated suspended matter subsequently being carried down the Grand. Levels were also higher at station E in 1986, which was located below the storm sewer drainage ditch and the Hwy 7 bridge. Wakeham *et al.* (1980) have identified urban runoff as a major source of PAH contamination in sediments and the water column.

Accumulation of metals in benthic tissue was also relatively low, though the data were limited. Arsenic, lead and cadmium showed differences in the levels of accumulation between upstream and downstream areas, with levels at station 0002 slightly higher than levels at station 0001. However, copper, mercury, zinc and arsenic all showed an increase in tissue-sediment ratios at station 0001 (Table 11) even though total body burdens were lower than at station 0002, which suggests that these metals were more available to biota. Since water column data indicate that bottom water levels of some contaminants were higher at this station and sediment levels show an increase in the levels of most metals at station 0003 to higher levels than at station 0001 these suggest that the WPCP discharge is contributing some contaminants to the water column at least and perhaps to the sediments as well. However, the lack of benthic invertebrate tissue data for station 0003 means that inferences regarding potential availability of metals from the WPCP cannot be drawn.

Tissue levels of contaminants in benthic invertebrates could not be related to levels in the water column or to either bulk sediment levels (all contaminants) or levels in the geochemical fractions (metals). The small sample size of the 1987 survey (limited to two stations) and the lack of biotic data from the more extensive sediment survey of 1986, precluded statistical analysis of this data and made the derivation of any sediment-biota relationships very tenuous. The inability to define any sediment-biota contaminant relationships is also due in part to the fact that the mechanisms of contaminant uptake by biota in natural systems are not yet fully understood. In addition, the analysis was hampered by the physical characteristics of the study area. The high energy environment that characterizes most flowing water means that sediments deposited in an area are subject to considerable resuspension and deposition of fine-particulate matter due to current action. Therefore, changes in sediment contaminant concentrations can occur both temporally and spatially as a result of purely physical processes. This presents difficulties in relating sediment concentration with concentrations in organism tissues. The latter would represent concentrations accumulated over the lifetime of the individual, while sediment concentrations would be accumulated over an unknown time period, which may vary from hours to months or years.

Tissue levels of metals in fish showed little change from station 0001 to 0003 except for cadmium, which was slightly lower at both station 0001 and station 0002. Levels of most metals in fish tissues were actually higher at station 0002, and parallels the levels in sediment and benthic invertebrates. Any increase in water or sediment levels below the WPCP were therefore, not reflected in fish tissue levels.

No significant accumulations of any organic compounds were noted, though levels of some of the chlorophenols were slightly higher in benthic organisms at station 0002 than at station 0001. Fish (rainbow darters) however, did show a steady increase in tissue levels of pentachlorophenol with distance downstream.

However, no clear conclusions could be drawn regarding the contribution of sediment contaminants to fish tissue concentrations. The analysis of fish tissues in relation to sediment contamination presents considerable difficulties. Bottom feeding fish can accumulate contaminants from two different media. They can acquire contaminants from the water column, through sorption onto external body surfaces, and they can also acquire contaminants through the ingestion of contaminated food items. It is at present difficult to differentiate the body burdens acquired from the sediment from the amount acquired from the water. Therefore, while fish provide an excellent means of assessing they biological availability of contaminants in a waterbody, they are unable to provide much insight into the availability of contaminants from specific sources such as the sediments. The use of sediment in-fauna appears to be a more appropriate means of assessing contaminant availability and uptake from sediment since these organisms are for the most part relatively sessile. Their virtually continuous exposure to sediment contaminants through ingestion of the solid phases as well as through surface adsorption from the interstitial water suggests that the contribution of contaminants from the dissolved phase in the water column would be minimal.

Availability from the sediments appears to be the major factor in regulating uptake of contaminants from the sediments. While organic matter can accumulate relatively greater amounts of contaminants, simply due to the greater number of binding sites available, this material is often not available to biota due to the strength of binding of contaminants to the sediment particles. However, due to equilibrium exchanges processes, relatively more contaminant may also be available in the interstitial water in such sediments. Therefore, while sediment-tissue concentration ratios may be low in areas of contaminated organic sediments, the total body burden may be higher than in areas of lower contaminant and sediment organic matter. In the latter, concentration ratios can often exceed a ratio of one:one, implying that uptake is greater in these areas.

Laboratory sediment bioassays revealed no toxicity from any of the Grand River sediments on either of the test species. During the ten day test period, some accumulation of contaminants was noted principally among the metals. Tissue levels of most metals were highest at station 0002. These results were consistent with the field results.

The benthic community underwent little change throughout the study area, with species composition being similar both upstream and downstream. An increase in biomass at station 0001 suggests the addition of nutrients and organic matter in this area.

However, only generalized conclusions can be derived from studies based on benthic communities. Responses on the community level are a combination of both natural environmental factors (i.e., substrate type, depth) and artificial (anthropogenic) factors (organic and inorganic contaminants, organic matter and physical alterations) and it is extremely difficult to isolate the effects of changes in one phase (e.g. sediment contaminant concentrations) except where such changes have had a pronounced effect.

As is apparent from the results of this survey, the Waterloo WPCP had little discernible effect on the river and the contribution of urban and rural non-point sources within the watershed resulted in a greater accumulation of contaminants in sediment and biota.

5. CONCLUSIONS

1. Discharge from the Waterloo WPCP resulted in higher levels of sodium, chloride, sulphate, some of the metals and conductivity in bottom water downstream. The discharge however, does not appear to be having any effect on the sediment downstream of the WPCP.

2. There was no increase in sediment metal concentrations below the WPCP. Levels were actually higher upstream where organic matter had accumulated. Contributions from urban/rural non-point sources appear to have more significant effects on sediment quality than the WPCP. Higher levels of lead and zinc were found in sediments below the drainage ditch discharges. Deposition of organic matter

in the river is temporally and spatially variable. Where organic matter is low, accumulation of metals appears to be mainly into the clays and Fe/Mn oxides. Where significant accumulations of fine organic matter occur, such as at the confluence of Laurel Creek, metals appear to be accumulating with the organic matter.

3. Levels of most organic compounds were below detection limits. However, PAHs in sediments were elevated at upstream areas, specifically in depositional areas such as occurred where Laurel Creek joins the Grand River. Levels in sediments were considerably higher in 1987 than in 1986.

4. The biological results showed that invertebrate tissue levels of metals were generally higher at stations upstream of the WPCP. Invertebrates did not appear to accumulate detectable levels of any organic compounds. Little difference was noted in metal levels in fish tissue between upstream and downstream areas and tissue levels of organics were all very low.

5. Laboratory sediment bioassays indicated that none of the sediments were toxic to the species tested. Accumulation of metals paralleled field results.

6. The slight increase in benthic biomass below the WPCP may be in response to the discharge of the nutrients N and P from the plant. Aside from this, no other impact on the benthic fauna was discernible.

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Appendix 1

7. Figures

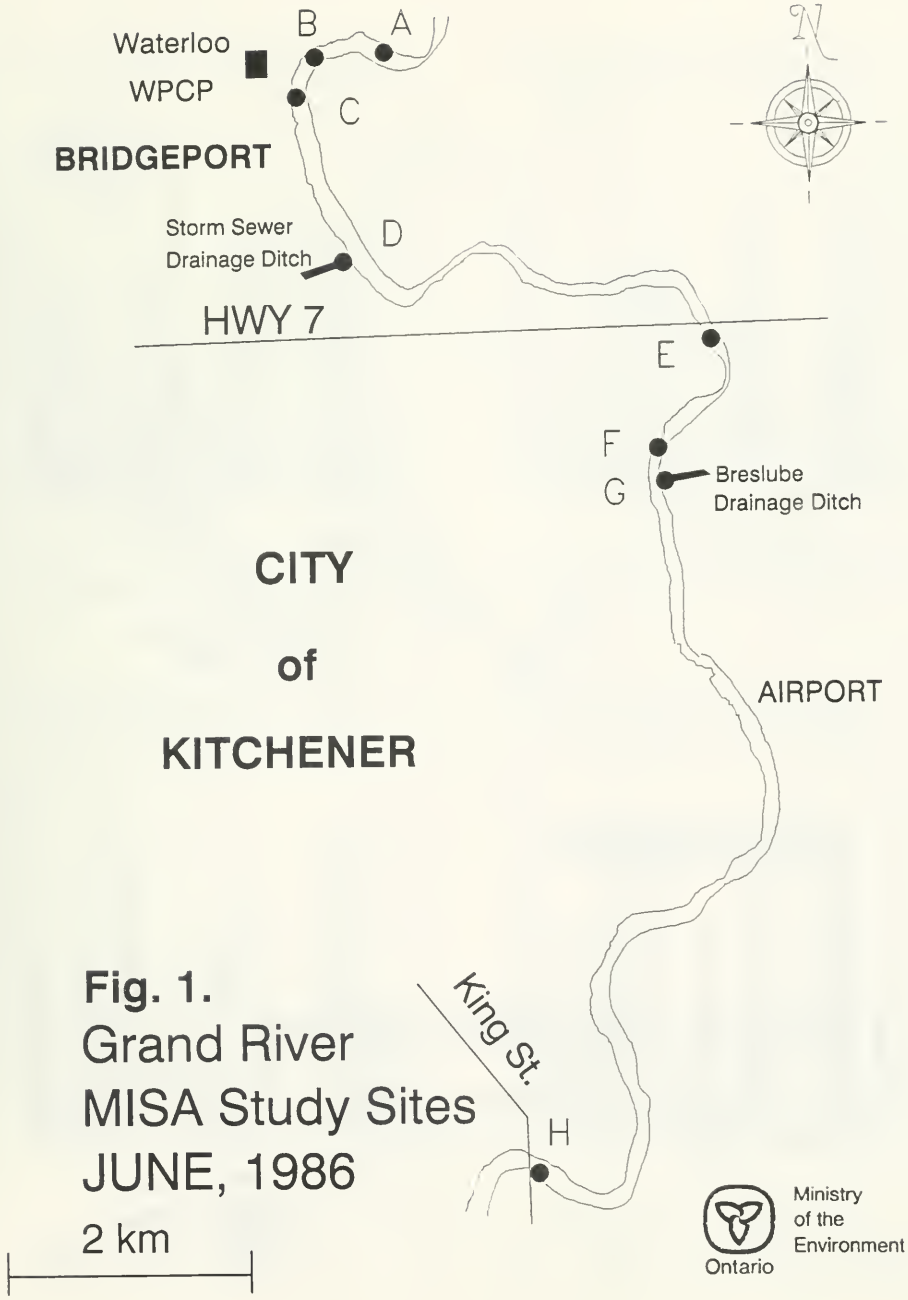


Fig. 1.
Grand River
MISA Study Sites
JUNE, 1986

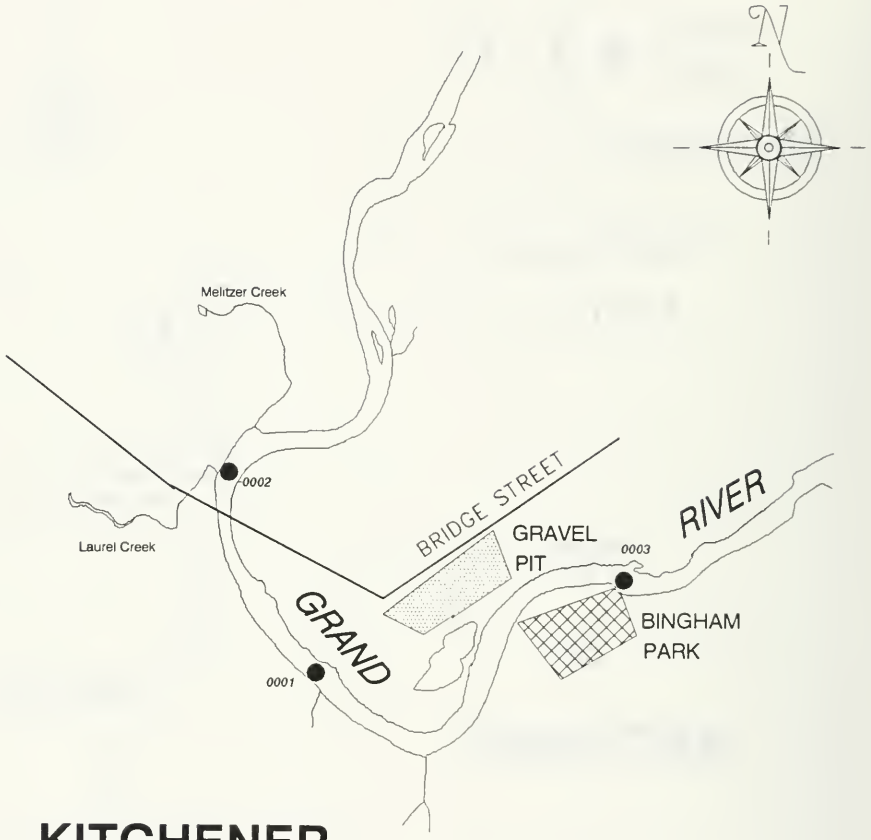


Fig. 2 GRAND RIVER

Location of Sampling Sites
May 1987.

2 km

Ontario Ministry of the Environment

Fig. 3a: Sediment Metal Levels
Grand River, June 1986

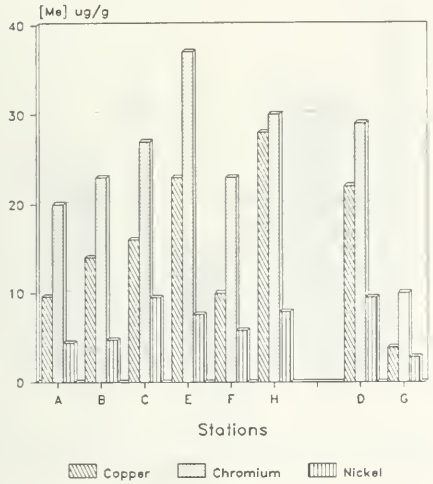


Fig. 3b: Sediment Metal Levels
Grand River, June 1986

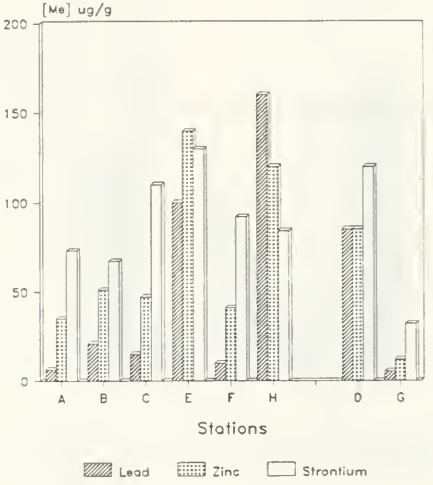


Fig. 3c: Sediment Metal Levels
Grand River, June 1986

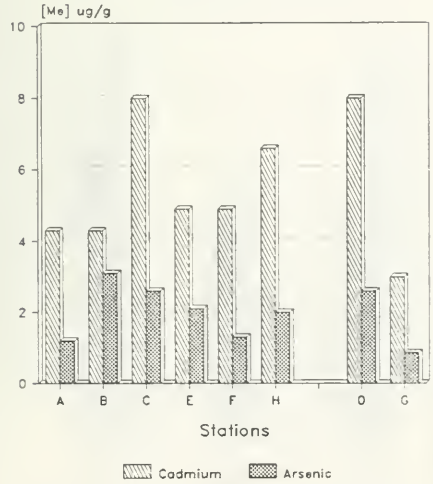


Fig. 3d: Sediment Metal Levels
Grand River, June 1986

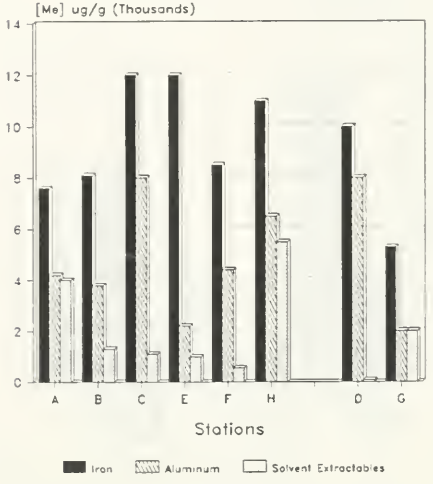


Fig. 4a: Sediment Metal Levels
Grand River, June 1987

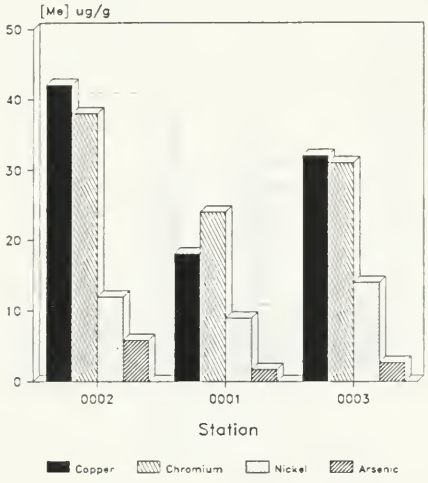


Fig. 4b: Sediment Metal Levels
Grand River, June 1987

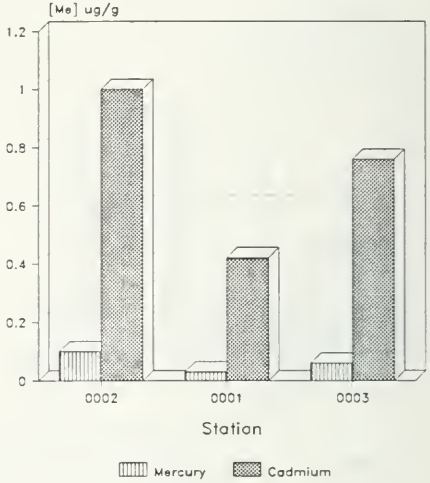


Fig. 4c: Sediment Metal Levels
Grand River, June 1987

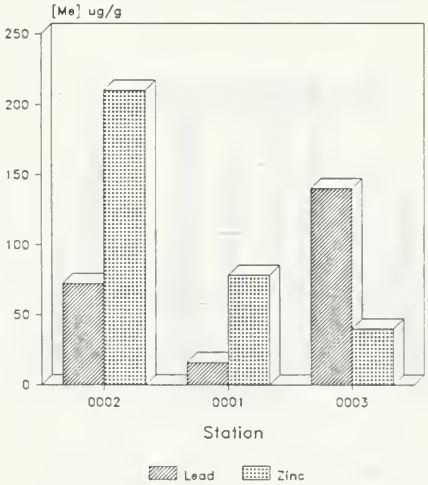
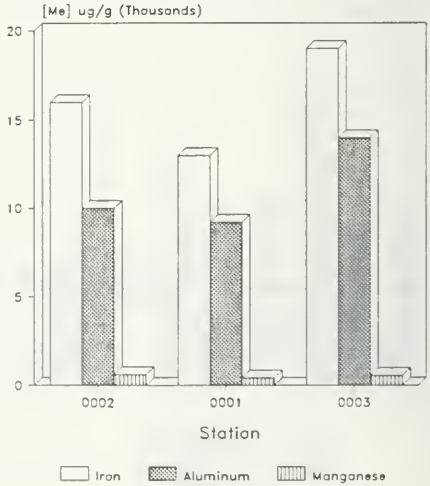


Fig. 4d: Sediment Metal Levels
Grand River, June 1987



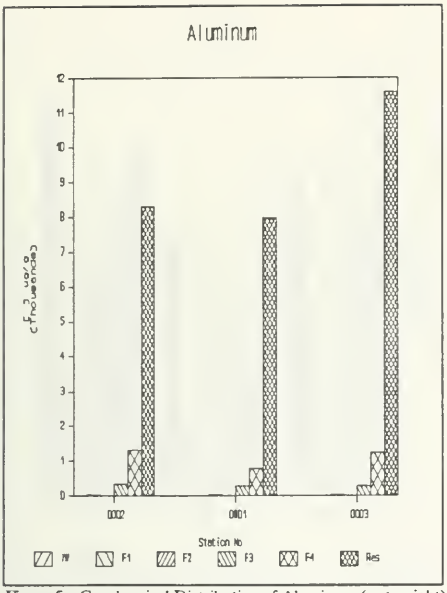


Figure 5a: Geochemical Distribution of Aluminum (wet weight)

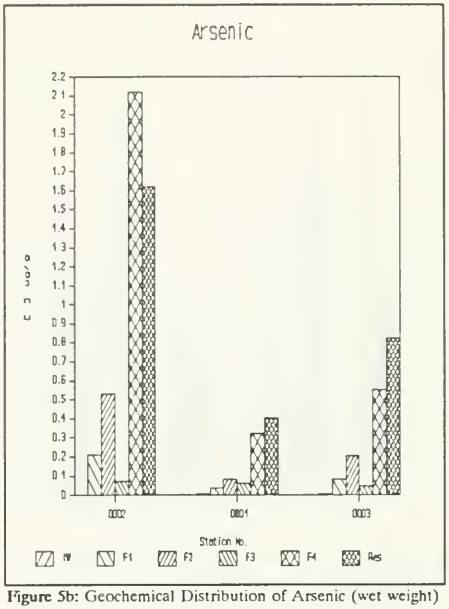


Figure 5b: Geochemical Distribution of Arsenic (wet weight)

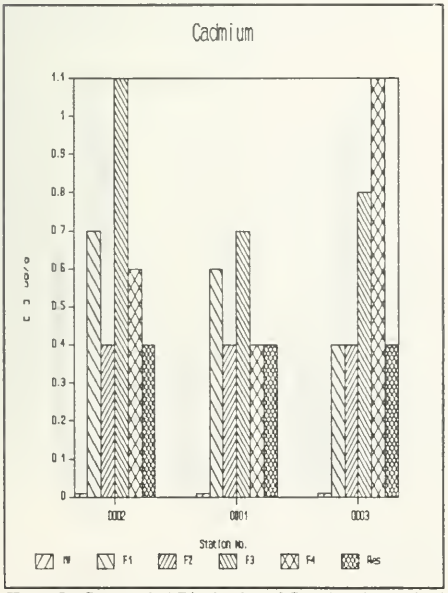


Figure 5c: Geochemical Distribution of Cadmium (wet weight)

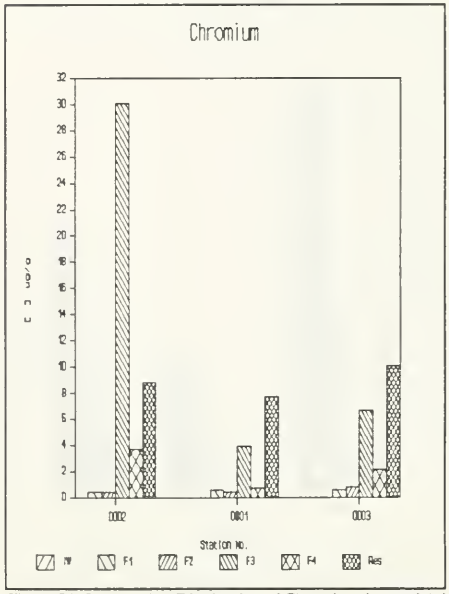


Figure 5d: Geochemical Distribution of Chromium (wet weight)

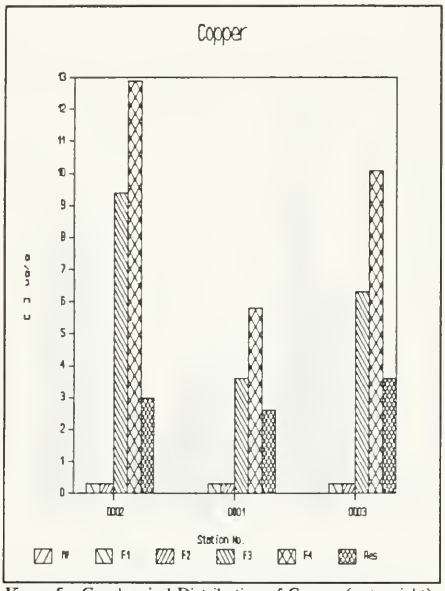


Figure 5e: Geochemical Distribution of Copper (wet weight)

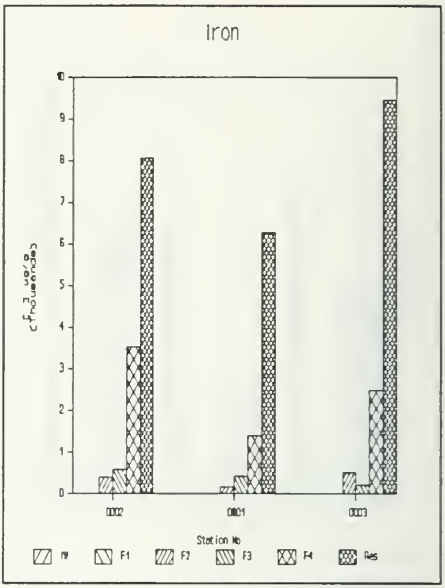


Figure 5f: Geochemical Distribution of Iron (wet weight)

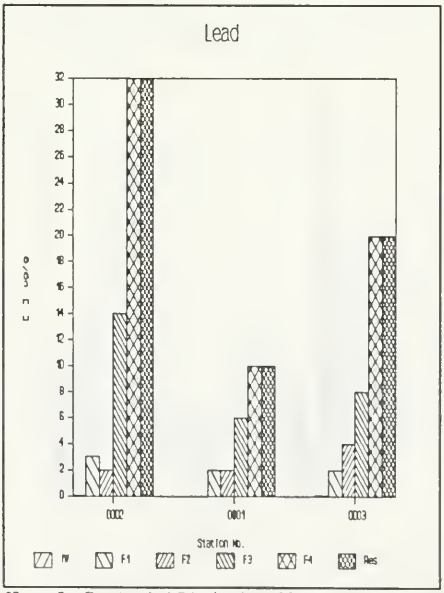


Figure 5g: Geochemical Distribution of Lead (wet weight)

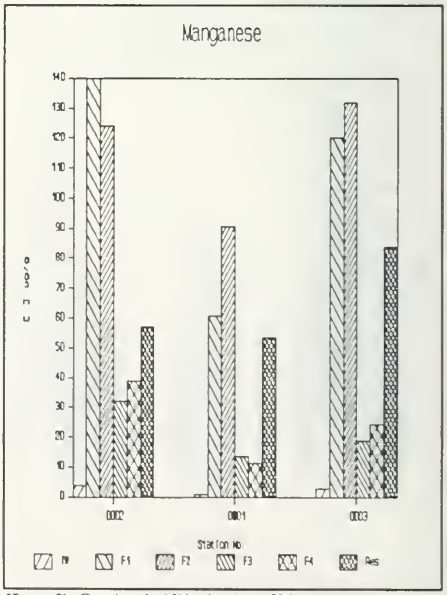


Figure 5h: Geochemical Distribution of Manganese (wet weight)

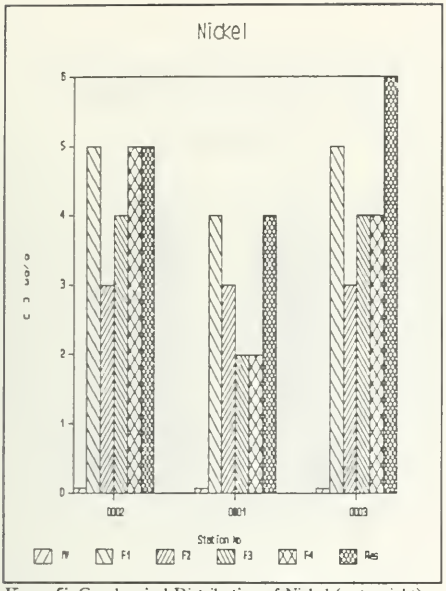


Figure 5i: Geochemical Distribution of Nickel (wet weight)

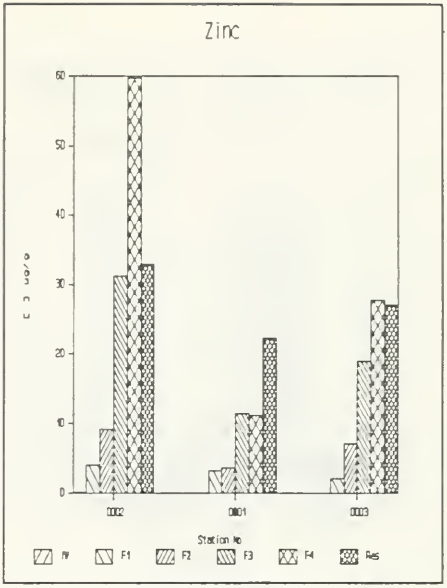
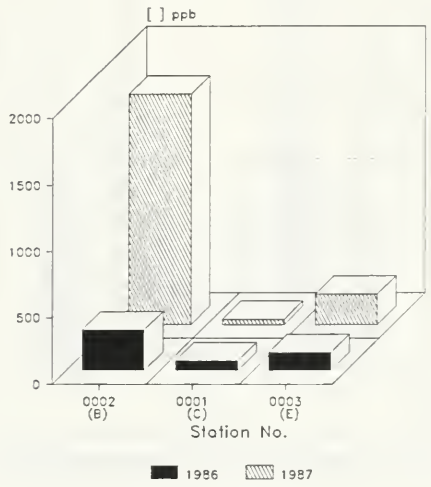


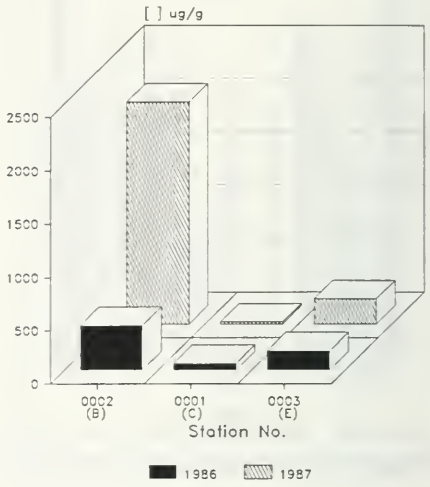
Figure 5j: Geochemical Distribution of Zinc (wet weight)

Fig. 6a: Sediment Benzo[a]pyrene Levels
Grand River 1986 – 1987



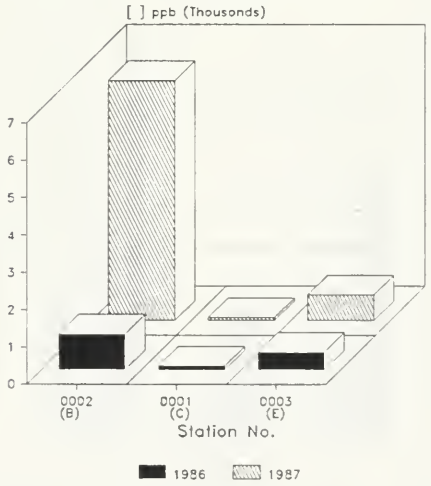
( ) denote 1986 stations

Fig. 6b: Sediment Chrysene Levels
Grand River 1986 – 1987



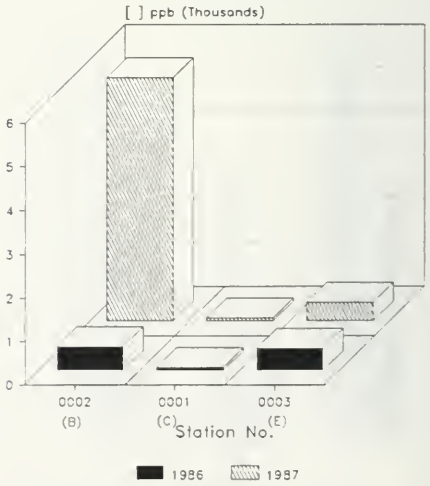
( ) denote 1986 stations

Fig. 6c: Sediment Fluoranthrene Levels
Grand River 1986 – 1987



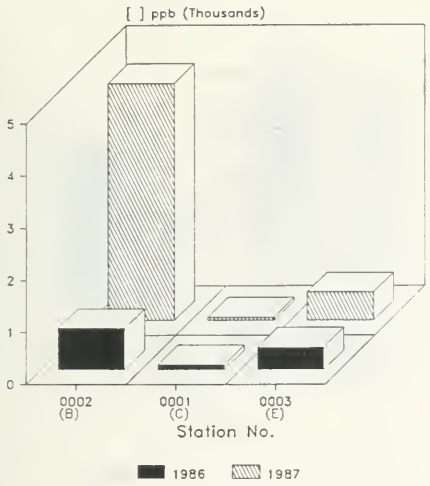
( ) denote 1986 stations

Fig. 6d: Sediment Phenanthrene Levels
Grand River 1986 – 1987



( ) denote 1986 stations

Fig. 6e: Sediment Pyrene Levels
Grand River 1986 – 1987



( ) denate 1986 stations

Fig. 6f: Total Sediment PAH,
Grand River 1986–1987

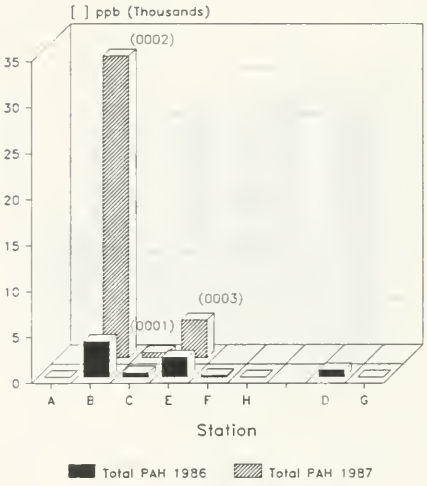
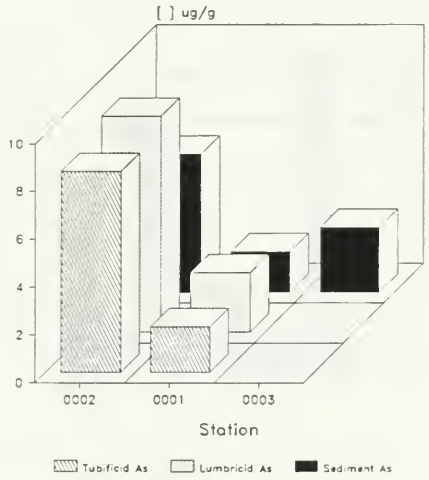
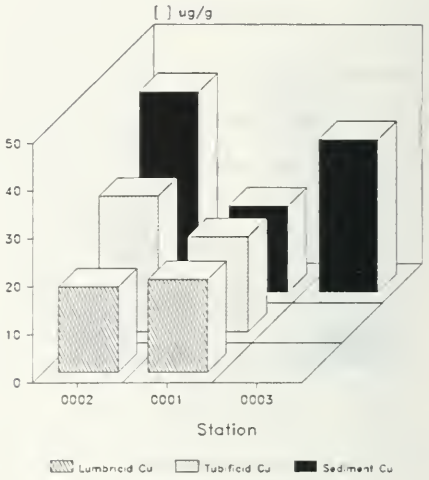


Fig. 7a: Sediment – Invertebrate Tissue Levels of Arsenic, 1987



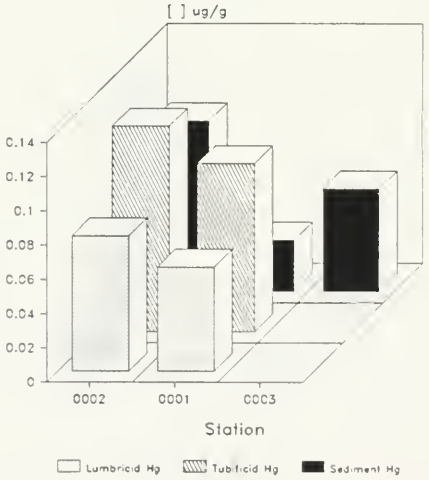
Tissue levels are gut corrected, dry weight

Fig. 7b: Sediment – Invertebrate Tissue Levels of Copper, 1987



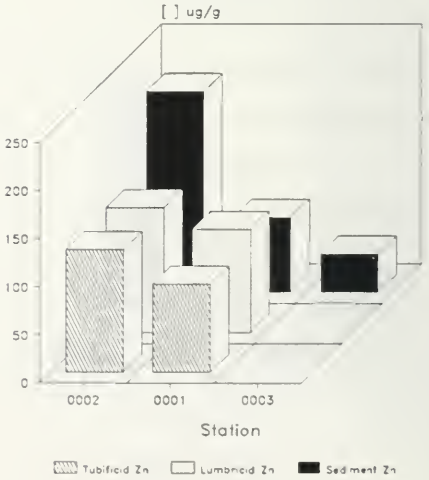
Tissue levels are gut corrected, dry weight

Fig. 7c: Sediment – Invertebrate Tissue Levels of Mercury, 1987



Tissue levels are gut corrected, dry weight

Fig. 7d: Sediment – Invertebrate Tissue Levels of Zinc, 1987



Tissue levels are gut corrected, dry weight

Fig. 8a: Sediment Bioassay Arsenic Accumulation

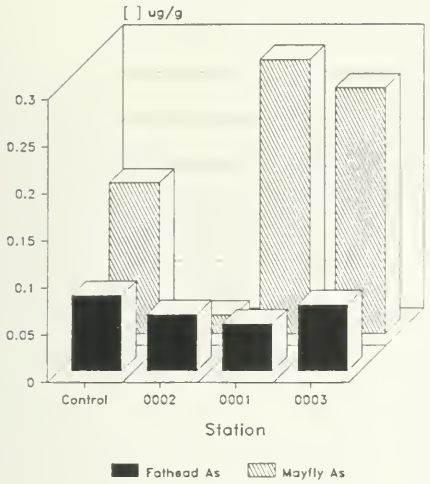


Fig. 8b: Sediment Bioassay Copper Accumulation

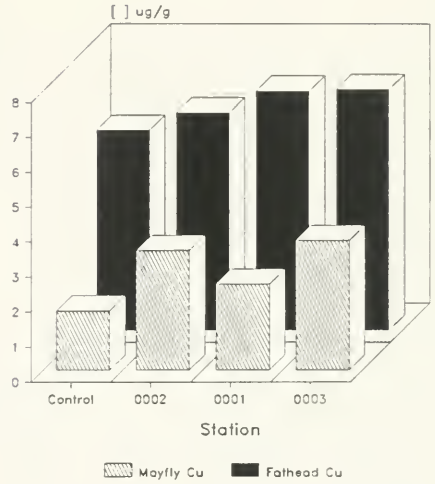


Fig. 8c: Sediment Bioassay Iron Accumulation

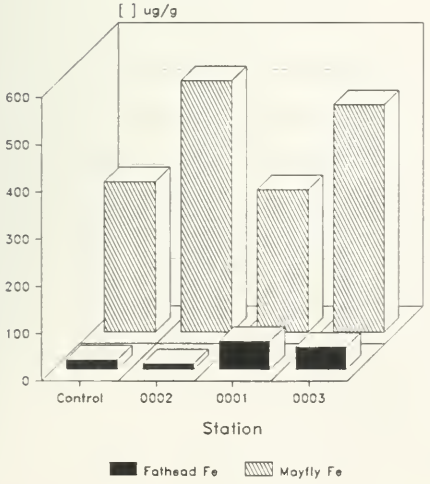
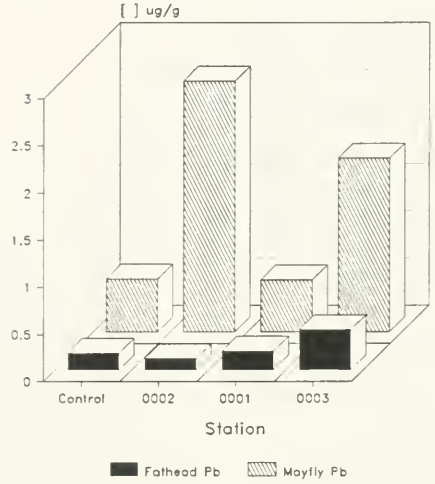


Fig. 8d: Sediment Bioassay Lead Accumulation



Appendix 2

8. Tables

TABLE 1 In-Place Pollutants Program

1987 Grand River Study

Water - Nutrients pH Ions

(MAY - JUNE)

Station	Depth	Conductivity @ 25 C	Hardness	Sodium	Potassium	Alkalinit	pH	Acidity Total	Fluoride	Chloride	Sulphate	Residue Filtrate	Residue Particulate	Turbidity	Colour true	Phosphorus	Nitr n Total	Ammonium Total Frac	Ammonium Total Reac	Nitrates Total Frac	Nitrates Total Reac	Nitrite Frac	Nitrite Reac	Phenolics	Chemical Oxygen Demand	Dissolved Organic Carbon	Dissol Inorga Carbo
	m	umho/cm	mg/l	mg/l	mg/l	mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	FORM	COL IRE	mg/l	mg/l	mg/l		mg/l		mg/l		ug/l	mg/l	mg/l	mg/
0002	0 1-0 2	467 0	204 0	15 4	2 63	178 2	8 58	-	0 09	21 2	39 2 CR	304 0	4 5	3 4	19 0	0 032	0 61	0 068		1 73		0 0595		-	17 6	5 0	4
0001	0 1-0 2	671 0	233 0	40 1	2 82	185 1	8 48	-	0 12	76 0	55 2 CR	416 0	6 4	1 8	21 0	0 027	0 69	0 074		1 67		0 0575		-	16 2	5 1	3
0003	0 1-0 3	736 0	246 0	53 7	3 71	190 7	8 27	-	0 22	84 5	61 3 CR	478 0	11 7	5 0	21 0	0 092	0 75	0 010		2 94 >		0 2350		-	21 9	5 4	4

KEY - NO DATA

CR CALCULATED RESULT

TABLE 2 In-Place Pollutants Program

1986 Grand River Study

Water - metals

(MAY-JUNE)

Location	Station	Depth	Field Ph	Field EH	Copper	Chromium	Mercury	Cadmium	Iron	Lead	Zinc	Arsenic	Manganese	Aluminium	Nickel
		m			mg/L	mg/L	ug/L	mg/L	mg/L	mg/L	mg/l	mg/L	mg/L	mg/l	mg/l
GRAND RIVER	0002	0 1-0 2	8 60	-	0 003	0 001	<0 01	<0 0003	0 180	<0 003	0 005	<0 001	0 041	0 058	0 004
	0001	0 1-0 2	8 50	-	0 001	0 005	<0 01	<0 0003	0 220	<0 003	<0 001	<0 001	0 019	0 082	<0 002
	0003	0 1-0 3	8 25	-	0 003	0 001	0 01	<0 0002	0 180	<0 003	0 005	<0 001	0 041	0 059	0 004

TABLE 3 In-Place Pollutants Program
1987 Grand River Study
Water - PCB & Pesticides
Units ng/L
(MAY-JUNE)

Station	Depth	Aldrin	A-BHC Hexa-chloro cyclo hexane	B-BHC Hexa-chloro cyclo hexane	G-BHC Hexa-chloro cyclo hexane	A Chlor-dane	G Chlor-dane	Dieldrin	DwDT meth-oxyclor	Endo-sulfan I	Octa Chloro-Styrene	Endo-sulfan II	Endrin	Endo-sulfan sulfate	Hepta-chlor epoxide	Hepta-chlor	Mirex	Oxy-chloro-dane	OP-DDT	PCB total	PP-DDD	PP-DDE	PP-DDT	Hexa-chloro-benzene
	m																							
0002	0 1-0 2	-	-	-	-	-	-	-	-	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	<1
0001	0 1-0 2	-	-	-	-	-	-	-	-	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	<1
0003	0 1-0 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

KEY < LOWER THAN DETECTION LIMIT
<I THIS LOW MEASUREMENT IS TENTATIVE - FOR INFORMATION ONLY
- NO DATA

TABLE 4 In-Place Pollutants Program
1987 Grand River Study
Water - Organics
Units ng/L
(MAY-JUNE)

Station	Depth	Hexa-chloro ethane	1 3 5 Trichloro benzene	1 2 4 Trichloro benzene	Hexa Chloro-butadiene	1 2 3 Trichloro benzene	2 4 5 Trichloro toluene	2 3 6 Trichloro toluene	1 2 3 5 Tetrachloro benzene	1 2 4 5 Tetrachloro benzene	2 6 a Trichloro toluene	Tetra-chloro-benzene	Penta-chloro-benzene	Toxa-Phene	Dicamba	2 4-Di Propionic Acid	2 4-Di chlorophenoxy Acetic Acid	2 4 5-Tri chlorophenoxy Acetic Acid	2 4-Di chlorophenoxy Buty ric Acid	Silvex	Picloram
	m																				
0002	0 1-0 2	<1	<5	< 5	<1	< 5	<5	<5	<1	<1	<5	<1	<1	-	<T 190	<100	<100	< 50	<200	< 20	-
0001	0 1-0 2	<1	<5	< 5	<1	< 5	<5	<5	<1	<1	<5	<1	<1	-	< 50	<100	<100	< 50	<200	< 20	-
0003	0 1-0 3														<T 220	<100	<100	< 50	<200	< 20	-

KEY < LOWER THAN DETECTION LIMIT
<I THIS LOW MEASUREMENT IS TENTATIVE - FOR INFORMATION ONLY
- NO DATA

TABLE 5 In-Place Pollutants Program
1987 Grand River Study
Water - Chlorophenols
Units ng/l
(MAY-JUNE)

Location	Station	Depth m	Trichorophenols 234	245	246	Tetrachlorophenols 2345	2356	Pentachloro-phenols
GRAND RIVER	0002	0 1-0 2	-	-	-	-	-	-
	0001	0 1-0 2	-	-	-	-	-	-
	0003	0 1-0 3	-	-	-	-	-	-

TABLE 6a In-Place Pollutants Program
1986 Grand River
Sediment - Percent Particle Size
Units um
(NOVEMBER)

Location	Station	Gravel >1000	Sand 1000-44	Silt 42 21-3 73	Clay 3 73-0 17
GRAND RIVER	A	0 0	40 80	41 50	9 80
	B	0 4	95 30	2 50	1 10
	C	0 6	48 10	32 60	17 70
	D	9 1	82 60	5 30	1 80
	I	4 8	78 10	12 10	3 60
	G	10 0	83 30	5 40	6 60
	G	19 3	73 8	4 7	1 8

TABLE 6b In-Place Pollutants Program
1987 Grand River
Sediment - Percent Particle Size
Units um
(MAY-JUNE)

Location	Station	Gravel >1000	Sand 1000-44	Silt 42 21-3 73	Clay 3 73-0 17
GRAND RIVER	0002	0 6	46 7	38 3	12 5
	0001	0 4	51 2	34 8	11 0
	0003	0 1	28 5	52 4	18 4

Table 7d In-Place Pollutants Program
Sediment - metals
Units as Given Dry Weight
(cont)

Location	Station	Field pH	Field EH	Loss on Ignition	Phosphorous	Total Kjeldahl Nitrogen	Total Organic Carbon	Copper	Chromium	Mercury	Cadmium	Iron	Lead	Zinc	Arsenic	Manganese	Aluminum	Nickel	Solvent Extractables	Selenium	Strontium	Beryllium	Cobalt	Vanadium
		pH	EH	%	mg/g	mg/g	mg/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g		
Grand River	A	-	-	3.70	0.92	1.20	24.0	9.6	20.0	0.01	< 0.20	7800	6.3	39.0	1.20	310	4200	4.4	4000	0.32	73	< 1.00	4.30	17.00
	B	-	-	2.00	0.49	0.40	6.2	14.0	23.0	0.01	0.26	6100	21.0	51.0	3.10	240	3400	4.7	1300	0.14	67	< 1.00	9.10	17.00
	C	-	-	0.04	0.23	0.10	< 5.0	3.9	10.0	0.03	< 0.20	5300	5.3	12.0	0.66	140	2000	2.6	2000	0.05	32	< 1.00	3.00	9.20
	C	-	-	2.40	0.67	0.60	8.90	16.00	27.00	< 0.01	< 0.20	12000	15.00	47.00	3.60	370	8000	9.50	1100	0.23	110	< 1.00	8.00	21.00
	D	-	-	0.70	0.26	0.20	< 5.0	22.00	29.00	0.01	< 0.20	1000	65.00	85.00	2.60	160	2700	5.90	71	0.14	120	< 1.00	< 4.00	10.00
	E	-	-	0.98	1.04	1.60	< 5.0	23.00	37.00	< 0.01	< 0.20	12000	100.00	140.00	2.10	400	2200	7.40	980	0.14	130	< 1.00	< 4.00	10.00
	F	-	-	1.60	0.63	1.20	< 5.0	10.00	23.00	0.01	< 0.20	8400	10.00	41.00	1.30	260	4400	5.60	910	0.14	92	< 1.00	4.40	17.00
	H	-	-	4.70	0.84	0.50	19.0	24.00	30.00	0.04	0.58	11000	160.00	170.00	2.00	470	6500	7.90	9100	0.23	44	< 1.00	6.90	20.00

Sediment

Location	Station	Field pH	Field EH	Loss on Ignition	Phosphorous	Total Kjeldahl Nitrogen	Total Organic Carbon	Copper	Chromium	Mercury	Cadmium	Iron	Lead	Zinc	Arsenic	Manganese	Aluminum	Nickel	Solvent Extractables
		pH	EH	%	mg/g	mg/g	mg/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
Grand River	A	-	-	6.00	0.63	2.40	38.0	15.0	27.0	0.07	0.34	12000	14.0	80.0	2.30	460	4100	7.2	1200
	B	-	-	0.64	0.26	0.30	5.6	6.1	14.0	0.03	< 0.20	5100	14.0	10.0	2.60	170	3300	1.1	470
	C	-	-	1.10	0.36	0.20	5.0	8.7	20.0	0.01	< 0.20	7400	13.0	27.0	2.10	370	4200	5.3	320
	D	-	-	0.87	0.22	0.10	5.00	23.00	27.00	0.01	< 0.20	8400	33.00	58.00	1.20	210	2300	4.50	1400
	F	-	-	0.63	0.43	0.70	12.0	6.00	29.00	0.01	< 0.20	7600	9.10	41.00	1.10	390	4200	5.60	470
	G	-		0.37	0.49	0.10	5.8	3.70	16.00	< 0.01	< 0.20	9500	12.00	34.00	1.60	290	2400	3.60	330
	G	-	-	0.89	0.38	0.30	5.6	7.10	20.00	< 0.01	< 0.20	10000	18.00	72.00	0.95	260	3100	4.90	960

Table 7b In-Place Pollutants Program

1987 Grand River/Canagagigue Creek Study

Metals

Units As Given, Dry Weight

(MAY-JUNE)

Location	Station	Field Ph	Field EH	Loss on Ignition %	Phosphorous mg/g	Total Kjeldahl mg/g	Total Organic Carbon mg/g	Copper ug/g	Chromium ug/g	Mercury ug/g	Cadmium ug/g	Iron ug/g	Lead ug/g	Zinc ug/g	Arsenic ug/g	Manganese ug/g	Aluminum ug/g	Nickel ug/g	Solvent Extractables ug/g
GRAND RIVER	0002	7 07	250 *	12 0	0 80	1 9 *	44 0 *	42 0 *	38 0	0 10 *	1 00 *	16000 *	72 0 *	210 0	5 60	600 0	10000	12 0 *	7810
	0001	7 28	- 220 *AV	6 6	0 90 *	2 3 *	22 0 AV	18 0 AV	24 0	0 03 AV	0 42 *AV	13000 AV	16 0 AV	78 0	1 70 AV	410 0 AV	9200 AV	9 0 *	2020
	0003	7 18	256 *	8 8 *	1 40 *	3 4 *	45 0 *	32 0 *	31 0	0 06	0 76 *	19000	140 0 *	40 0	2 70	540 0	14000	14 0 *	1650

(OCTOBER)

Location	Station	Field Ph	Field EH	Loss on Ignition %	Phosphorous mg/g	Total Kjeldahl Nitrogen mg/g	Total Organic Carbon mg/g	Copper ug/g	Chromium ug/g	Mercury ug/g	Cadmium ug/g	Iron ug/g	Lead ug/g	Zinc ug/g	Arsenic ug/g	Manganese ug/g	Aluminum ug/g	Nickel ug/g	Solvent Extractables ug/g
GRAND RIVER	0002	-	-	2 9	0 62	0 70	19 0 *	16 0	19 0	0 04	0 33	7900 *	30 0	79 0	2 00	270 0	4200	5 8	260
	0001	-	-	4 7	0 53	1 49	33 0 *	20 0	8 0	0 03	0 40	9300 *	14 0	65 0	2 10	330 0	6800	6 0	623
	0003	-	-	4 7	0 69	1 45	29 0 *	20 0	19 0	0 05	0 44	9400 *	27 0	86 0	2 00	340 0	6000	8 9	74

TABLE 8 In-Place Pollutants Program

1987 Grand River Study

Sediment - Geochemical Distribution of metals

UNITS ug/g wet weight

ARSENIC

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	0 003	0 211	0 531	0 072	2 120	1 620	1 320	4 343
GRAND RIVER	0001	0 009	<0 040	0 080	0 060	0 323	0 404	1 320	0 867
GRAND RIVER	0003	0 005	0 084	0 207	0 048	0 555	0 824	2 050	1 834

KEY < Less than detection limit

ZINC

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	0 13	4 1	9 2	31 2	59 8	32 9	117 0	137 2
GRAND RIVER	0001	0 03	3 2	3 7	11 5	11 2	22 3	55 2	51 9
GRAND RIVER	0003	0 04	2 1	7 2	19 0	27 7	27 0	79 9	83 0

KEY < Less than detection limit

LEAD

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	< 0 05	< 3 00	< 2 0	14	32	5	45	53
GRAND RIVER	0001	< 0 02	< 2 00	< 2 0	6	10	3	20	20
GRAND RIVER	0003	< 0 05	< 2 00	4 0	8	20	5	40	38

KEY < Less than detection limit

CADMIUM

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	< 0 01	0 7	< 0 4	1 1	0 8	0 4	0 5	2 4
GRAND RIVER	0001	< 0 01	0 6	< 0 4	0 7	< 0 4	0 4	0 5	1 3
GRAND RIVER	0003	< 0 01	< 0 4	< 0 4	0 8	1 1	0 4	0 5	1 9

KEY < Less than detection limit

CHROMIUM

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	< 0 01	< 0 4	< 0 4	30 1	3 7	8 8	23 9	62 8
GRAND RIVER	0001	< 0 01	0 6	< 0 4	3 9	0 7	7 7	11 5	13 3
GRAND RIVER	0003	< 0 01	0 6	0 8	6 7	2 1	10 1	17 9	20 3

KEY < Less than detection limit

ALUMINUM

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	0 70	27 6	4 5	340	1330	8300	12800	10002
GRAND RIVER	0001	0 84	27 7	5 0	289	786	7990	12700	9098
GRAND RIVER	0003	0 16	29 3	9 4	285	1240	11600	15000	13184

KEY < Less than detection limit

NICKEL

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	0 07	5	3	4 0	5 0	5	11	22
GRAND RIVER	0001	0 07	4	3	< 2 0	< 2 0	4	8	13
GRAND RIVER	0003	0 07	5	3	4 0	< 0	8	11	22

KEY < Less than detection limit

IRON

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	11 80	8 8	402	586	3540	8080	13300	12600
GRAND RIVER	0001	2 26	5 3	182	414	1410	6270	11200	8281
GRAND RIVER	0003	6 17	12 4	525	212	2490	9460	14600	12690

KEY < Less than detection limit

MANGANESE

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	3 90	140 0	124 0	32 2	38 9	57 0	368	342 1
GRAND RIVER	0001	1 00	80 7	90 8	13 8	11 2	53 6	271	220 3
GRAND RIVER	0003	2 82	120 0	132 0	18 8	24 4	83 8	486	370 0

KEY < Less than detection limit

COPPER

LOCATION	STATION	IW	F1	F2	F3	F4	RES	BULK	Sum
GRAND RIVER	0002	0 012	< 0 3	< 0 3	9 4	12 9	3 0	19 0	25 3
GRAND RIVER	0001	< 0 008	< 0 3	< 0 3	3 6	5 8	2 6	9 1	12 0
GRAND RIVER	0003	< 0 008	< 0 3	< 0 3	6 3	10 1	3 6	17 2	20 0

KEY < Less than detection limit

TABLE 10A In-Place Pollutants Program

Grand River 1986

Sediment - Organics

Units ng/g Dry Weight

(JUNE)

	Station	Hexa-chloro ethane	1 3 5 Trichloro benzene	1 2 4 Trichloro benzene	Hexa Chloro-butadiene	1 2 3 Trichloro benzene	2 4 5 Trichloro toluene	2 3 6 Trichloro toluene	1 2 3 5 Tetrachloro benzene	1 2 4 5 Tetrachloro benzene	2 6 Trichloro toluene	Tetra-chloro-benzene	Penta-chloro-benzene	DiCamba	2 4D Propionic Acid	Dichloro-phenoxy-acetic	Silvex	Trichloro-phenoxy-acetic	2 4-Dichloro-phenoxy butyric
GRAND RIVER	A	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1	<100	<100	< 100	< 50	<50	<200
	B	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1	<100	<100	< 100	< 50	<50	<200
	G	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1	<100	<100	< 100	< 50	<50	<200
	C	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1	<100	<100	< 100	< 50	<50	<200
	D	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1	<100	<100	< 100	< 50	<50	<200
	E	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1	<100	<100	< 100	< 50	<50	<200
	F	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1	<100	<100	< 100	< 50	<50	<200
	H	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1	<100	<100	< 100	< 50	<50	<200

TABLE 10b: In-Place Pollutants Program

Grand River Study

Sediment - Organics

Units ng/g Dry weight

(MAY-JUNE)

	Station		Hexa-chloro ethane	1 3 5 Trichloro benzene	1,2,4 Trichloro benzene	Hexa Chloro-butadiene	1 2 3 Trichloro benzene	2 4 5 Trichloro toluene	2 3 6 Trichloro toluene	1,2 3,5 Tetrachloro benzene	1 2 4 5 Tetrachloro benzene	2 6 Trichloro toluene	Tetra-chloro-benzene	Penta-chloro-benzene
GRAND RIVER	0002	100	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0001	100	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0003	100	<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1

(OCTOBER)

	Station		Hexa-chloro ethane	1 3 5 Trichloro benzene	1 2 4 Trichloro benzene	Hexa Chloro-butadiene	1 2 3 Trichloro benzene	2 4 5 Trichloro toluene	2 3 6 Trichloro toluene	1 2 3 5 Tetrachloro benzene	1,2 4 5 Tetrachloro benzene	2 6 Trichloro toluene	Tetra-chloro-benzene	Penta-chloro-benzene
GRAND RIVER	0002		<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0001		<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1
	0003		<1	<2	< 2	<1	<2	<1	<1	<1	<1	<1	<1	<1

TABLE 11. Benthic Invertebrates - Tissue-Sediment Concentration Ratios Grand River, 1987.

Station No.	Copper	Chromium	Mercury	Cadmium	Iron	Lead
Oligochaetes						
0002	0.67	0.10	1.20	0.50	0.15	0.36
0001	1.10	0.12	3.26	0.62	0.17	0.54
Lumbricids						
0002	0.42	0.06	0.79	0.34	0.11	0.23
0001	1.07	0.11	2.03	0.76	0.19	0.42

Station No.	Zinc	Arsenic	Manganese	Aluminum	Nickel
Oligochaetes					
0002	0.61	1.45	0.15	0.10	0.20
0001	1.18	1.14	0.21	0.10	0.37
Lumbricids					
0002	0.62	1.56	0.09	0.04	0.11
0001	1.37	1.44	0.22	0.10	0.33

Sediment concentrations used in the calculations were on a dry weight (ug/g) basis. Biota values used were wet weight converted to dry weight and corrected for gut contents according to the formula in Persaud et al (1987). Bioaccumulation Factors were computed according to the formula:

$$C_{ct} = C_{org} - (C_{sed} \times K_{asn}) \times (1 - K_{asn})^{-1}$$

where C_{ct} = gut corrected tissue concentration; C_{org} = organism (dry weight) contaminant concentration; C_{sed} = bulk sediment concentration and; K_{asn} = residue after ashing organism at 500° C (as a percentage).

Tissue-sediment concentration ratios were computed according to the formula:

$$\text{Ratio} = C_{ct} / C_{sed}$$

TABLE 12a In-Place Pollutants Program
1986 Grand River Study
Sediment - PAHs
UNITS ng/g Dry weight

LOCATION	STATION	DIBENZO(a h) ANTHRACENE	BENZO(g h i) PERYLENE	NAPHTHALENE	ACENAPHTHYLENE	ACENAPHTHENE	FLUORENE	PHENANTHRENE	ANTHRACENE	FLUORANTHRENE	PYRENE	BENZO(a) ANTHRACENE	CHRYSENE	BENZO(a) PYRENE	INDENO (1,2,3-cd) PYRENE
GRAND RIVER	A	-	-	-	-	-	-	-	-	TR	TR	-	-	-	TR
GRAND RIVER	B	-	88 00	-	-		TR 60 00	549 00	123 00	959 00	799 00	605 00	420 00	305 00	-
GRAND RIVER	G	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	-	-		TR -	-	-	70 00	-	105 00	96 00	77 00	62 00	73 00	-
	D	-	-	-	-	-	-	157 00		TR 200 00	208 00	153 00	78 00	-	-
	E	-	-	66 00		TR 130 00	94 00	514 00	146 00	476 00	429 00	TR	180 00	134 00	-
	F	TR	TR	-	-	-	-	TR	TR	47 00	49 00	TR	TR	TR	83 00
	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 12b In-Place Pollutants Program
1987 Grand River Study
Sediment - PAHs
UNITS ug/g Dry weight

STATION	DIBENZO(a h) ANTHRACENE	BENZO(g h i) PERYLENE	NAPHTHALENE	ACENAPHTHYLENE	ACENAPHTHENE	FLUORENE	PHENANTHRENE	ANTHRACENE	FLUORANTHRENE	PYRENE	BENZO(a) ANTHRACENE	CHRYSENE	BENZO(k) FLUORANTHENE	BENZO(b) FLUORENE	BENZO(a) PYRENE	INDENO (1,2,3-cd) PYRENE
0002	0 63	1 31	0 18	0 07	0 41	0 56	5 56	1 14	6 42	4 54	1 83	2 08	3 05	3 05	1 73	1 27
0001	0 04 <T	0 04 <T	0 04 <T	0 04 <T	0 04 <T	0 04 <T	0 07 <T	0 01 <T	0 08	0 06 <T	0 03	0 02	0 02 <T	0 06 <T	0 04 <T	0 04 <T
0003	0 06	0 24	0 04 <T	0 04 <T	0 04 <T	0 04 <T	0 43	0 07	0 69	0 54	0 24	0 24	0 49	0 49	0 23	0 23

KEY <T - A measurable trace amount

TABLE 13 In-Place Pollutants Program

1987 Grand River

Chlorophenols

Units ng/g Dry weight

(MAY-JUNE)

Location	Station	Trichlorophenol			Tetrachlorophenol		Penta-
		234	245	246	2345	2356	chlorophenol
GRAND RIVER	0002	<100	<50	<50	< 50	< 50	< 50
	0001	<100	<50	<50	< 50	< 50	< 50
	0003	<100	<50	<50	< 50	< 50	< 50

TABLE 14 In-Place Pollutants Program

1987 Grand River Study

Benthic Invertebrates - Metals

UNITS: ug/g Wet Weight (Not corrected for gut content)

Station	Biota	Copper	Chromium	Cadmium	Iron	Mercury	Lead	Zinc	Arsenic	Manganese	Aluminum	Nickel	% Solids
0002	Oligochaetes	5 26	0 90	0 098	447	0 019	4 43	22 8	2 09	18 23	195	0 48	22 26
0002	Lumbricids	2 56	0 52	0 047	333	0 014	3 10	22 3	2 21	11 54	82	0 22	21 18
0002	Oligochaetes	3 84	0 48	0 065	390	0 019	2 75	18 4	0 57	13 73	186	0 36	20 32
0002	Lumbricids	3 26	0 48	0 067	318	0 011	2 63	19 5	0 65	9 92	116	0 25	18 34
0001	Oligochaetes	3 14	0 54	0 042	380	0 015	1 41	14 6	0 31	14 53	172	0 55	18 24
0001	Chironomids	4 42	0 58	0 068	476	0 016	0 75	12 0	0 19	20 80	245	0 41	11 54
0001	Lumbricids	3 06	0 50	0 051	426	0 010	1 10	17 0	0 39	15 20	170	0 49	21 09

TABLE 15 In-Place Pollutants Program

1987 Grand River Study

Benthic Invertebrates - PCBs & Pesticides

UNITS ug/g wet weight (not corrected for gut content)

Station	Biota	HCB	HEPTA-CHLOR	HEPTA-CHLOR EPOXIDE	ALDRIN	DIELDRIN	A-BHC	B-BHC	D-BHC	A-CHLOR-DANE	G-CHLOR-DANE	PCB	OXY-CHLORDANE	PP-DDE	PP-DDD	PP-DDT	OP-DDT	ENDO-SULFAN I	ENDO-SULFAN II	DIELDRIN	ENDRIN	ENDO-SULFAN SULFATE	METHOXY-CHLOR	% LIPID	%ASH
0002	OLIGOCHAETES	< 0.001	< 0.001	< 0.002	< 0.001	< 0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	1.120	1.74
0002	LIMNEICIDS	< 0.001	< 0.001	< 0.002	< 0.001	< 0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	0.733	1.57
0002	OLIGOCHAETES	< 0.001	< 0.001	< 0.002	< 0.001	< 0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	=	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	0.480	2.09
0002	LIMNEICIDS	< 0.001	< 0.001	< 0.002	< 0.001	< 0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	0.541	1.99
0001	OLIGOCHAETES	< 0.001	< 0.001	< 0.002	< 0.001	< 0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	0.362	1.99
0001	CHIRONOMIDS	< 0.001	< 0.001	< 0.002	< 0.001	< 0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	=	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	0.152	3.47
0001	LIMNEICIDS	< 0.001	< 0.001	0.009	< 0.001	< 0.002	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	0.431	3.09

#Fly < less than detection limit

- no data

TABLE 16 In-Place Pollutants Program

1987 Grand River Study

Benthic Invertebrates - Chlorinated Aromatics

UNITS ug/g Wet Weight (Not corrected for gut content)

Station #	Biota	Hexa-chloro-ethane	1,3,5 Trichloro-benzene	1,2,4 Trichloro-benzene	Hexa-chloro-butadiene	1,2,3 Trichloro-benzene	2,4,5 Trichloro-toluene	2,3,6 Trichloro-toluene	1,2,3,5 Tetrachloro-benzene	1,2,4,5 Tetrachloro-benzene	2,6a Trichloro-toluene	1,2,3,4 Tetrachloro-benzene	Pentachloro-benzene	Octachloro-styrene	Toxaphene
0002	OLIGOCHAETES	< 0.001	< 0.01	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0002	LUMBRICIDS	< 0.001	< 0.01	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0002	OLIGOCHAETES	< 0.001	< 0.01	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0002	LUMBRICIDS	< 0.001	< 0.01	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	0.002	< 0.001	-	< 0.01
0001	OLIGOCHAETES	0.002	< 0.01	< 0.01	0.004	< 0.005	-	-	< 0.001	< 0.001	< 0.01	0.002	< 0.001	-	< 0.01
0001	CHIRONOMIDS	< 0.001	< 0.01	< 0.01	0.006	< 0.005	-	-	< 0.001	< 0.001	< 0.01	< 0.001	< 0.001	-	< 0.01
0001	LUMBRICIDS	0.002	< 0.01	< 0.01	< 0.001	< 0.005	-	-	< 0.001	< 0.001	< 0.01	0.002	< 0.001	-	< 0.01

KEY < Less than detection limit

\- No data

TABLE 17 In-Place Pollutants Program

1987 Grand River Study

Benthic Invertebrate - Chlorophenols

UNITS ug/g Wet Weight (Not corrected for gut content)

Station	Type	2,3,4- Trichloro-phenol	2,3,5,6- Tetrachloro-phenol	2,3,4,5- Tetrachloro-phenol	3,4,5- Trichloro-phenol	2,4,6- Trichloro-phenol	Penta-chloro-phenol
0002	Oligochaetes	< 0.01	< 0.002	< 0.003	< 0.003	< 0.010	< 0.005
0002	Lumbricids	< 0.01	< 0.005	< 0.005	< 0.010	< 0.010	< 0.002
0002	Oligochaetes	< 0.01	0.017	< 0.005	0.075	< 0.003	0.149
0002	Lumbricids	< 0.01	< 0.005	< 0.005	< 0.010	< 0.010	< 0.004
0001	Oligochaetes	< 0.01	< 0.005	< 0.005	0.022	< 0.010	0.016
0001	Chironomids	< 0.01	< 0.005	< 0.005	0.256	< 0.010	0.101
0001	Lumbricids	< 0.01	< 0.005	< 0.005	< 0.010	< 0.010	< 0.005

KEY < Less than detection limit

TABLE 18 In-Place Pollutants Program

1987 Grand River Study

Fish - metals

Units: ug/g

Station	AGE	Organism	Copper Cu	Chromium Cr	Mercury Hg	Cadmium Cd	Iron Fe	Lead Pb	Zinc Zn	Arsenic As	Manganese Mn	Aluminum Al	Nickel Ni	% Solids
0002	2 YR	RAINBOW DARTER	4 73	0 89	0 114	0 006	48	0 25	48 9	0 96	11 19	28	0 48	29 81
0002	2 YR	LONGNOSE DACE	2 47	0 00	0 109	0 001	47	0 18	28 5	0 57	4 41	0	0 00	29 48
0001	1 YR	LONGNOSE DACE	4 87	0 80	0 080	0 003	36	0 05	31 0	0 15	4 33	22	0 86	30 54
0001	2 YR	WHITE SUCKER	4 65	0 57	0 052	0 008	41	0 23	16 2	0 39	5 16	22	0 45	23 04
0001	1-2 YR	RAINBOW DARTER	4 22	0 81	0 112	0 006	29	0 12	37 8	0 50	8 14	17	0 53	29 58
0003	1 YR	WHITE SUCKER	5 88	0 96	0 044	0 028	130	0 60	36 1	0 63	11 94	59	0 56	24 50
0003	1 YR	RAINBOW DARTER A	4 27	0 80	0 107	0 010	33	0 19	40 8	0 69	9 44	13	0 51	28 79
0003	1 YR	RAINBOW DARTER B	6 10	0 80	0 085	0 014	31	0 19	38 4	0 27	7 77	18	0 50	29 32

TABLE 19 In-Place Pollutants Program
1987 Grand River Study
Sculpins and Fish - PCBs
Units ug/g

Station	Type	Aldrin	a-BHC Hexachlorocyclohexane	B-BHC Hexachlorocyclohexane	A-Chlordane	G-Chlordane	Dieldrin	DMDT methoxychlor	Endosulfan I	Endosulfan II	Endrin	Endosulfan sulphate	Heptachlor epoxide	Heptachlor I	Mirex	Oxychlordane	DD-DDT (total)	PCB	DD-DDD	DD-DDE	DD-DDT	% Lipid	% Ash
0002	Rainbow Darter	0 000	0 002	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 002	0 000	0 000	0 000	NA	0 000	0 00	0 000	0 023	0 000	6 020	3 72
0002	Longnose Dace	0 005	0 002	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 002	0 000	0 000	0 000	NA	0 000	0 00	0 000	0 032	0 000	7 430	3 98
0001	Longnose Dace	0 003	0 004	0 000	0 000	0 000	0 004	0 000	0 000	0 000	0 000	0 004	0 000	0 000	0 000	NA	0 000	0 00	0 005	0 035	0 000	7 800	4 05
0001	White Sucker	0 000	0 005	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 005	0 000	0 000	0 000	NA	0 000	0 00	0 000	0 028	0 000	2 340	3 94
0001	White Sucker	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	NA	0 000	0 00	0 000	0 000	0 000	2 160	3 34
0001	Rainbow Darter	0 000	0 004	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	NA	0 000	0 00	0 000	0 030	0 000	7 000	4 02
0003	Emerald Shiner	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	NA	0 000	0 00	0 018	0 000	0 000	2 260	4 12
0003	Rainbow Darter	0 000	0 004	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 004	0 004	0 000	0 000	NA	0 000	0 00	0 000	0 011	0 000	4 650	4 83
0003	Rainbow Darter	0 000	0 041	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 000	0 004	0 000	0 000	0 000	NA	0 000	0 49	0 000	0 000	0 000	5 210	NA

TABLE 20 In-Place Pollutants Program
1987 Grand River Study
Sculpins and Fish - Chlorinated Aromatics
Units ug/g

Station #	Type	Hexachloroethane	1 3 5 Trichlorobenzene	1 2 4 Trichlorobenzene	1 2 3 Trichlorobenzene	Hexachlorobutadiene	2 4 5 Trichlorotoluene	2 3 6 Trichlorotoluene	2 6a Trichlorotoluene	1 2 3 5 Tetrachlorobenzene	1 2 4 5 Tetrachlorobenzene	1 2 3 4 Tetrachlorobenzene	Pentachlorobenzene	Octachlorostyrene	Toxaphene
0002	Rainbow Darter	0 004	0 000	0 000	0 008	0 008	NA	NA	0 000	0 000	0 000	0 012	0 000	0 000	0 000
0002	Longnose Dace	0 007	0 000	0 000	0 011	0 011	NA	NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000
0001	Longnose Dace	0 005	0 000	0 000	0 005	0 005	NA	NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000
0001	White Sucker	0 005	0 000	0 000	0 006	0 006	NA	NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000
0001	White Sucker	0 003	0 000	0 000	0 002	0 000	NA	NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000
0001	Rainbow Darter	0 004	0 000	0 000	0 005	0 005	NA	NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000
0003	Emerald Shiner	0 005	0 000	0 000	0 008	0 008	NA	NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000
0003	Rainbow Darter	0 005	0 000	0 000	0 005	0 005	NA	NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000
0003	Rainbow Darter	0 000	0 000	0 000	0 000	0 000	NA	NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000

TABLE 21 In-Place Pollutants Program
1987 Grand River Study
Sculpins and Fish - Chlorophenols
Units ug/g

STATION	ORGANISM	Trichlorophenol					Penta-chlorophenol
		234	245	246	2345	2356	
2	Rainbow Darter	0 000	0 000	0 000	0 000	0 000	0 043
2	Longnose Dace	0 000	0 000	0 000	0 000	0 000	0 054
1	Longnose Dace	0 000	0 000	0 000	0 000	0 000	0 049
1	White Sucker	0 000	0 000	0 000	0 000	0 000	0 020
1	White Sucker	0 000	0 000	0 000	0 000	0 000	0 015
1	Rainbow Darter	0 000	0 000	0 000	0 000	0 000	0 058
3	Emerald Shiner	0 000	0 000	0 000	0 000	0 000	0 093
3	Rainbow Darter	0 000	0 000	0 000	0 000	0 000	0 079
3	Rainbow Darter	0 000	0 000	0 000	0 000	0 000	0 078

TABLE 22 In-Place Pollutants Program
1987 Grand River Study
Sculpins and Fish - PAH
Units mg\kg

Station	Type	Phen-anthrene	Anth-racene	Flour-anthrene	Flourene	Pyrene	Benz-(a) an-thracene	Chrysene	Benzo-(e)-pyrene	(B)	Benzofluoranthene B(l) (j)	(K)		Perylene	Benzo (a)-Pyrene	Benzo-(ghi)-perylene	Dibenz-(a h) an-thracene	Indeno-(1 2 3-cd) Pyrene	Benzo(b) chrysene	Anthan-threne	Coro-nene	Dimethyl-Benz(a) anthracene
0002	Rainbow Darter	NC	NC	NC	NC	NC	NC	NC	NC	NC	NA	NC	NC	NC	NC	NC	NC	NC		NA	NA	NA
0002	Longnose Dace	NC	NC	NC	NC	NC	NC	NC	NC	NC	NA	NC	NC	NC	NC	NC	NC	NC		NA	NA	NA
0001	Longnose Dace	NC	NC	NC	NC	NC	NC	NC	NC	NC	NA	NC	NC	NC	NC	NC	NC	NC		NA	NA	NA
0001	White Sucker	NC	NC	NC	NC	NC	NC	NC	NC	NC	NA	NC	NC	NC	NC	NC	NC	NC		NA	NA	NA
0001	White Sucker	NC	NC	NC	NC	NC	NC	NC	NC	NC	NA	NC	NC	NC	NC	NC	NC	NC		NA	NA	NA
0001	Rainbow Darter	NC	NC	NC	NC	NC	NC	NC	NC	NC	NA	NC	NC	NC	NC	NC	NC	NC		NA	NA	NA
0003	Emerald Shiner	NC	NC	NC	NC	NC	NC	NC	NC	NC	NA	NC	NC	NC	NC	NC	NC	NC		NA	NA	NA
0003	Rainbow Darter	NC	NC	NC	NC	NC	NC	NC	NC	NC	NA	NC	NC	NC	NC	NC	NC	NC		NA	NA	NA
0003	Rainbow Darter	0 142	0 059	0 021	0 000	0 012	0 000	0 000			NA	0 000	0 000	0 000	0 000	0 000	0 000	0 000		NA	NA	NA

TABLE 23 In-Place Pollutants Program

1987 Grand River Study

Sediment Bioassay Bioaccumulation Results metals

UNITS ug/g wet weight (not corrected for gut content)

LOCATION	STATION	ORGANISM	[% Solids]	Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Zn
GRAND R - CAN CR	CONTROL	MAYFLIES	[12 16]	194	0 16	0 172	0 75	1 59	364	0 69	20 6	0 015	0 51	23 1
GRAND R - CAN CR	CONTROL	MAYFLIES	[12 12]	207	0 18	0 166	0 89	1 72	383	0 67	25 2	0 012	0 78	20 8
GRAND R - CAN CR	CONTROL A	FATHEADS	[22 89]	46	0 11	0 040	0 44	S 26	81	0 16	3 1	0 200	0 24	35 1
GRAND R - CAN CR	PRECONTROL	MAYFLIES	[13 44]	111	0 15	0 246	0 77	1 76	208	0 32	9 6	0 014	0 62	24 6
GRAND R - CAN CR	PRECONTROL	FATHEADS	[23 80]	7	0 06	0 067	0 36	6 08	20	0 34	1 3	0 221	< 0 05	37 1
GRAND R - CAN CR	PRECONTROL	FATHEADS	[23 73]	8	0 06	0 041	0 39	S 84	19	0 03	1 3	0 246	0 22	34 0
GRAND RIVER	2	MAYFLIES	[11 36]	216	< 0 02	0 129	1 20	3 41	532	2 66	23 6	0 016	0 56	25 4
GRAND RIVER	2A	FATHEADS	[22 36]	12	0 06	0 075	0 24	6 24	28	0 12	1 1	0 238	< 0 10	40 4
GRAND RIVER	1	MAYFLIES	[11 93]	155	0 29	0 101	0 52	2 44	302	0 55	12 7	0 012	0 33	23 6
GRAND RIVER	1A	FATHEADS	[22 88]	60	< 0 05	0 051	0 53	6 86	112	0 20	3 7	0 238	0 12	33 4
GRAND RIVER	3	MAYFLIES	[11 75]	245	0 26	0 142	1 14	3 70	481	1 84	18 4	0 016	0 87	27 1
GRAND RIVER	3A	FATHEADS	[23 80]	54	0 06	0 079	0 57	6 99	118	0 48	3 4	0 240	0 32	41 8
GRAND RIVER	3A	FATHEADS	[23 22]	43	0 07	0 068	0 60	6 83	105	0 38	2 8	0 229	0 29	40 2

KEY <Less than detection limit

TABLE J4 In-Place Pollutants Program

1987 Grand River Study

Sediment Biaccumulation Equilts PCB's & Pesticides

UNITS ug/g wet weight (wet corrected for gut content)

LOCATION	STATION	ORGANISM	#ORGANISMS	% LIPID	% ASH	HCB	MIREX	g-BHC	d-BHC	ALPHA-CHLORDANE	GAMMA-CHLORDANE	OXY-CHLORDANE	PP-DDE	PP-DDD	PP-DDT	OO-DDT	a-ENDO-SULFAN	b-ENDO-SULFAN	DIELDRIN	ENDRIN	ENDO-SO4	METHOXY-CHLOR	PCB
GR R-CAN CB CTRL	CONTROL	MAYFLIES	1 737	2 112	1 82	0 003	< 0 001	< 0 003	< 0 001	< 0 002	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	0 007	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 08	< 0 001	< 0 001	< 0 01
GR R-CAN CB CTRL	CONTROL A	Fathead05	1 789	3 732	2 74	0 005	< 0 001	< 0 002	< 0 001	< 0 002	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	0 011	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 00	< 0 001	< 0 001	< 0 01
GR R-CAN CB CTRL	PRECONTROL	MAYFLIES	0 726	1 906	1 46	0 017	< 0 001	< 0 002	< 0 001	< 0 C02	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	0 030	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 00	< 0 001	< 0 001	< 0 01
GR R-CAN CB CTRL	PRECONTROL	Fathead05	3 327	5 401	2 35	0 006	< 0 001	< 0 002	< 0 001	< 0 002	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	0 005	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 00	< 0 001	< 0 001	< 0 01
GRAND River	2	MAYFLIES	1 689	2 017	1 51	0 026	< 0 001	< 0 002	< 0 001	< 0 002	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 01	< 0 001	< 0 001	< 0 01
GRAND River	2A	Fathead05	3 856	2 207	1 66	0 002	< 0 001	< 0 002	< 0 001	< 0 002	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 00	< 0 001	< 0 001	< 0 01
GRAND River	1	MAYFLIES	1 651	2 172	2 22	0 002	< 0 001	< 0 002	< 0 001	< 0 003	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	< 0 001	0 004	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 00	< 0 001	< 0 001	< 0 01
GRAND River	1R	Fathead05	1 772	4 103	3 16	0 008	< 0 001	< 0 003	< 0 001	< 0 002	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 00	< 0 001	< 0 001	0 06
GRAND River	3	MAYFLIES	1 761	2 564	1 61	0 004	< 0 001	< 0 002	< 0 001	< 0 C22	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 00	< 0 001	< 0 001	< 0 01
GRAND River	3A	Fathead05	3 410	5 655	2 62	< 0 001	< 0 001	< 0 003	< 0 001	< 0 002	< 0 001	< 0 0012	< 0 0012	< 0 0012	< 0 0012	< 0 0012	-	< 0 001	0 010	< 0 001	< 0 001	< 0 001	< 0 001	< 0 001	< 0 00	< 0 001	< 0 001	< 0 01

#fv < Less than detection limit

- No data

TABLE 25 In-Place Pollutants Program

1987 Grand River Study

Sediment Bioassay Bioaccumulation Results Chlorinated Aromatics

UNITS ug/g wet weight (Not corrected for gut content)

STATION	ORGANISM	HEXACHLORO -ETHANE	135-TCB	124-TCB	HEXACHLORO -BUTADIENE	123-TCB	245-TCT	236-TCT	1235-TCB	1245-TCB	26A-TCT	1234-TCB	PENTACHLORO BENZENE	OCTACHLORO STYRENE	TOXAPHENE
CONTROL	MAYFLIES	< 0 001	< 0 010	< 0 010	0 006	< 0 005	-	-	< 0 001	< 0 001	< 0 010	0 030	0 020	-	< 0 01
CONTROL A	FATHEADS	< 0 001	0 336	< 0 010	0 077	0 077	-	-	< 0 001	< 0 001	< 0 010	0 058	0 029	-	< 0 01
PRECONTROL	MAYFLIES	0 023	< 0 010	< 0 010	0 029	0 029	-	-	0 010	0 010	< 0 010	< 0 001	0 050	-	< 0 01
PRECONTROL	FATHEADS	< 0 001	0 238	< 0 010	0 053	0 053	-	-	< 0 001	< 0 001	< 0 010	0 037	0 067	-	< 0 01
2	MAYFLIES	< 0 001	< 0 010	< 0 010	< 0 001	< 0 005	-	-	< 0 001	< 0 001	< 0 010	0 030	0 022	-	< 0 01
2A	FATHEADS	< 0 001	< 0 010	< 0 010	0 025	< 0 005	-	-	< 0 001	< 0 001	< 0 010	0 024	0 021	-	< 0 01
1	MAYFLIES	< 0 001	< 0 010	< 0 010	0 025	< 0 005	-	-	< 0 001	< 0 001	< 0 010	0 059	< 0 001	-	< 0 01
1A	FATHEADS	< 0 001	< 0 010	< 0 010	0 015	< 0 005	-	-	< 0 001	< 0 001	< 0 010	0 058	< 0 001	-	< 0 01
3	MAYFLIES	< 0 001	< 0 010	< 0 010	0 010	< 0 005	-	-	< 0 001	< 0 001	< 0 010	< 0 001	0 027	-	< 0 01
3A	FATHEADS	< 0 001	< 0 010	< 0 010	0 009	< 0 005	-	-	< 0 001	< 0 001	< 0 010	0 019	0 015	-	< 0 01

KEY < Less than detection limit

\- No data

TABLE 26 In-Place Pollutants Program

1987 Grand River Study

Sediment Bioassay Bioaccumulation Results Chlorophenols

UNITS ug/g wet weight (not corrected for gut content)

STATION	ORGANISM	234-TRI-CHLOROPHENOL	2345-TETRA-CHLOROPHENOL	2356-TETRA-CHLOROPHENOL	345-TRI-CHLOROPHENOL	246-TRI-CHLOROPHENOL	PENTA-CHLOROPHENOL
CONTROL	MAYFLIES	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	< 0 005
CONTROL A	FATHEADS	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	< 0 005
PRECONTROL	MAYFLIES	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	0 053
PRECONTROL	FATHEADS	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	< 0 005
2	MAYFLIES	< 0 01	< 0 005	< 0 005	0 019	< 0 01	< 0 003
2A	FATHEADS	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	< 0 003
1	MAYFLIES	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	< 0 005
1A	FATHEADS	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	< 0 005
3	MAYFLIES	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	< 0 005
3A	FATHEADS	< 0 01	< 0 005	< 0 005	< 0 010	< 0 01	0 010

KEY < Less than detection limit

TABLE 27: Correlation Coefficients (Spearman Rank) for Sediment Metals and Organic Carbon and for Sediment Metals and Solvent Extractables (significance level in parentheses).

	Sediment TOC 1986 (June)	Sediment TOC 1987	Solvent Extractables 1987
sediment copper	-.1160 (.7954)	.9276 (.0381)	.7928 (.2705)
sediment chromium	-.0896 (.8413)	.4928 (.2705)	.7537 (.0919)
sediment mercury	.3985 (.3729)	.6088 (.1734)	.2609 (.5596)
sediment cadmium	.2744 (.2533)	.7714 (.0845)	.5429 (.2248)
sediment iron	-.1160 (.6854)	.7714 (.0845)	.6571 (.1417)
sediment lead	-.1739 (.6973)	.4857 (.2774)	.2571 (.5653)
sediment zinc	-.3769 (.3994)	-.2571 (.5653)	.0286 (.9491)
sediment arsenic	-.3189 (.4758)	.8407 (.0601)	.4058 (.3641)
sediment manganese	.2319 (.6041)	.7143 (.1102)	.7714 (.0845)
sediment aluminum	.4058 (.3641)	.8286 (.0639)	.7714 (.0845)
sediment nickel	- .1160 (.7954)	.7714 (.0845)	.6571 (.1417)

1987 correlation data is combined data from May-June and October surveys.

Correlations significant at the 95% level appear in bold type.

TABLE 28: DISTRIBUTION, DENSITY, AND BIOMASS ESTIMATES OF MAJOR MACROBENTHIC TAXA, GRAND RIVER, MAY-JUNE 1987.

All values are expressed on a per square meter basis. Biomass values calculated on wet weight basis.

	Station 0002		Station 0001		Station 0003	
	Average # Organisms	Biomass (gms)	Average # Organisms	Biomass (gms)	Average # Organisms	Biomass (gms)
ARTHROPODA						
Class Insecta						
O. Ephemeroptera					15	0.0282
O. Odonata						
O. Trichoptera						
O. Coleoptera	179	0.2409	77	0.0454	15	
O. Diptera						
F. Chironomidae	601	0.3758	800	1.2829	981	0.3815
F. Ceratopogonidae	15		92	0.0483	15	
Class Crustacea						
O. Amphipoda						
O. Isopoda	892	1.3047	31	0.1616	153	0.2379
MOLLUSCA						
Class Gastropoda	92	0.3258	15			
Class Pelecypoda			15			
ANNELIDA						
Class Hirudinea					15	
Class Oligochaeta	8,979	15.1826	17,207	47.6636	9,607	11.9599
TOTAL # ORGANISMS	**10,758**		**18,237**		**10,801**	
TOTAL BIOMASS		**17.4298**		**49.2018**		**12.6075**
CORRECTED BIOMASS (+ 10%)		**19.17**		**54.12**		**13.87**

TABLE 29: BENTHIC MACROINVERTEBRATE TAXA OF THE GRAND RIVER, MAY-JUNE, 1987

	STATION NUMBER (#/m^2)		
	0002	0001	0003
DIPTERA			
Chironomidae			
Chironominae			
Chironomus sp.	306	1,149	
Chironomus plumosus grp.			
Phaenopsectra sp.			77
Polypedilum (Pentapedilum) sp.			383
Tanytarsus sp.		77	
Orthocladiinae			
Cricotopus (Cricotopus) sp.	153	77	1,149
Tanypodinae			
Procladius sp.	77		
Ceratopogonidae			
Palpomyia sp.grp.	77	77	77
COLEOPTERA			
Elmidae			
Dubiraphia sp.	77		77
ISOPODA			
Asellidae			
Asellus sp.	689		536
PELECYPODA			
Sphaeriidae			
Pisidium casertanum		77	
HIRUDINEA			
Erpobdellidae			
Helobdella sp.			77
OLIGOCHAETA			
Tubificidae			
Limnodrilus hoffmeisteri	7,278	10,572	7,738
L. cervix/claparedianus		1,226	
Tubifex tubifex	306		306
immatures with capilliform setae			1,379
immatures without capilliform setae	2,298	6,206	996
Lumbriculidae			
Lumbriculus sp.		306	306
Total Number of Organisms	**11,261**	**19,767**	**13,407**
Species Diversity (H')	**1.634**	**1.711**	**2.252**
Species Richness (S.R.)	**0.857**	**0.809**	**1.263**
Evenness (J')	**0.516**	**0.540**	**0.609**